consulting engineer

Austrian Hydro-Plant

Contractors and Consultants

The Optimum Boiler Water

Technical Publicity

The Assembly Problem

Flow Problem

Models for Plant Layout

Industrial Dust Control

October 1953

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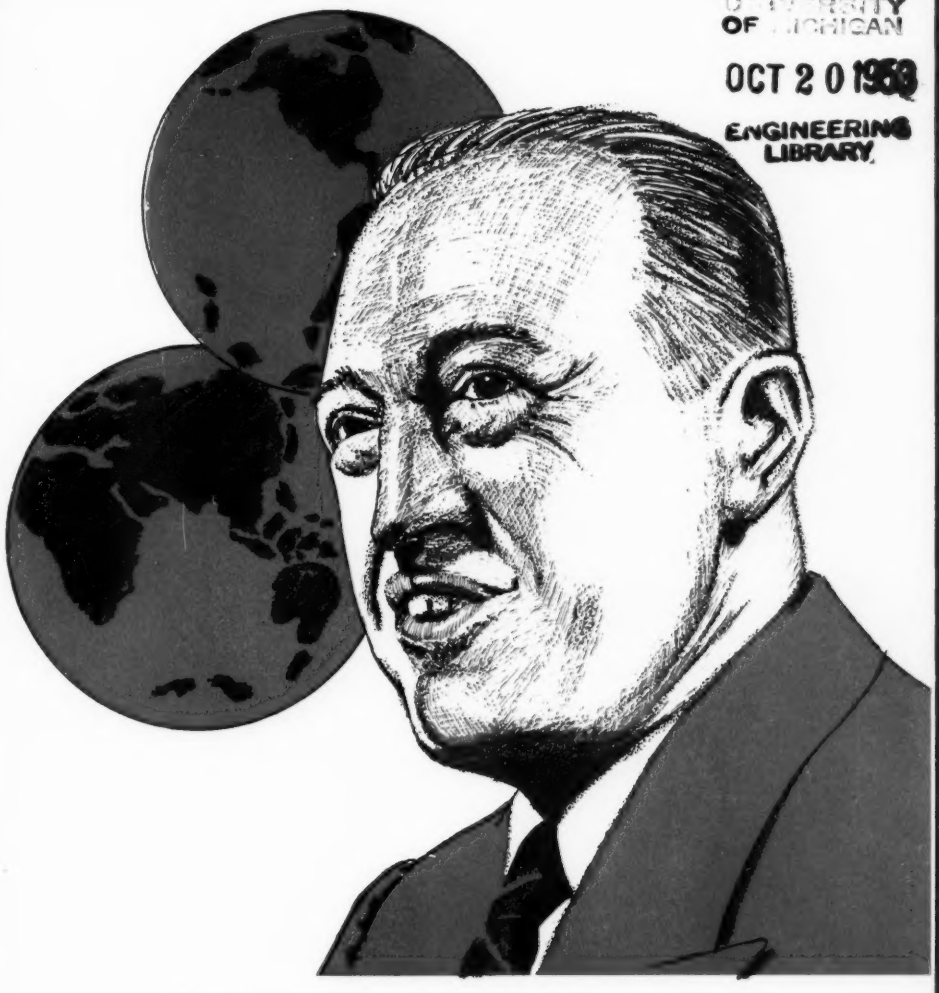

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(Continued on page 8)

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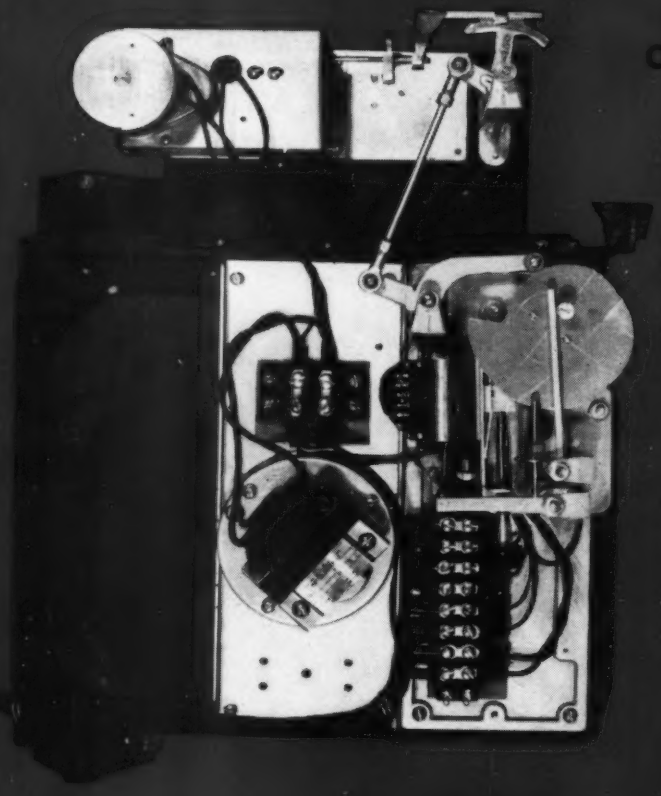

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VOLUME 2
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consulting engineer

OCTOBER 1953

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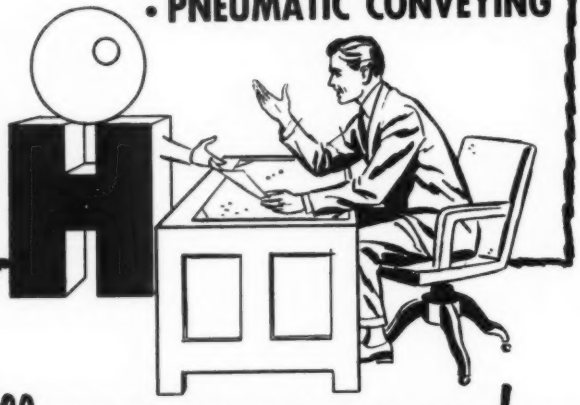

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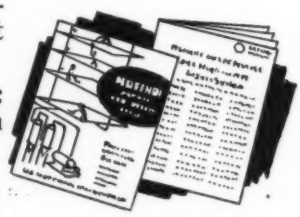

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Very truly yours

"A MAGAZINE IS PEOPLE" is a trite statement, but it is also a truth which is often overlooked. I am inclined to believe that our economists, historians, and sociologists underplay this fact and allow us to think about a *company* as something abstract. Without people any organization, whether it is Industry and Power Publications or Westinghouse, would be a collection of inanimate objects that produce nothing and help no one.

Too many publishers, even if they are thinking of their publications in terms of people, do not include as many people as they should. They realize their product depends upon the creative abilities of editors and sales promotion men, upon the sound judgment of their business manager, upon the persuasive qualities of their sales staff, upon the favorable disposition of advertisers, and upon the diligent application of clerks and circulation personnel. But they forget sometimes the most important people of all — the *readers*.

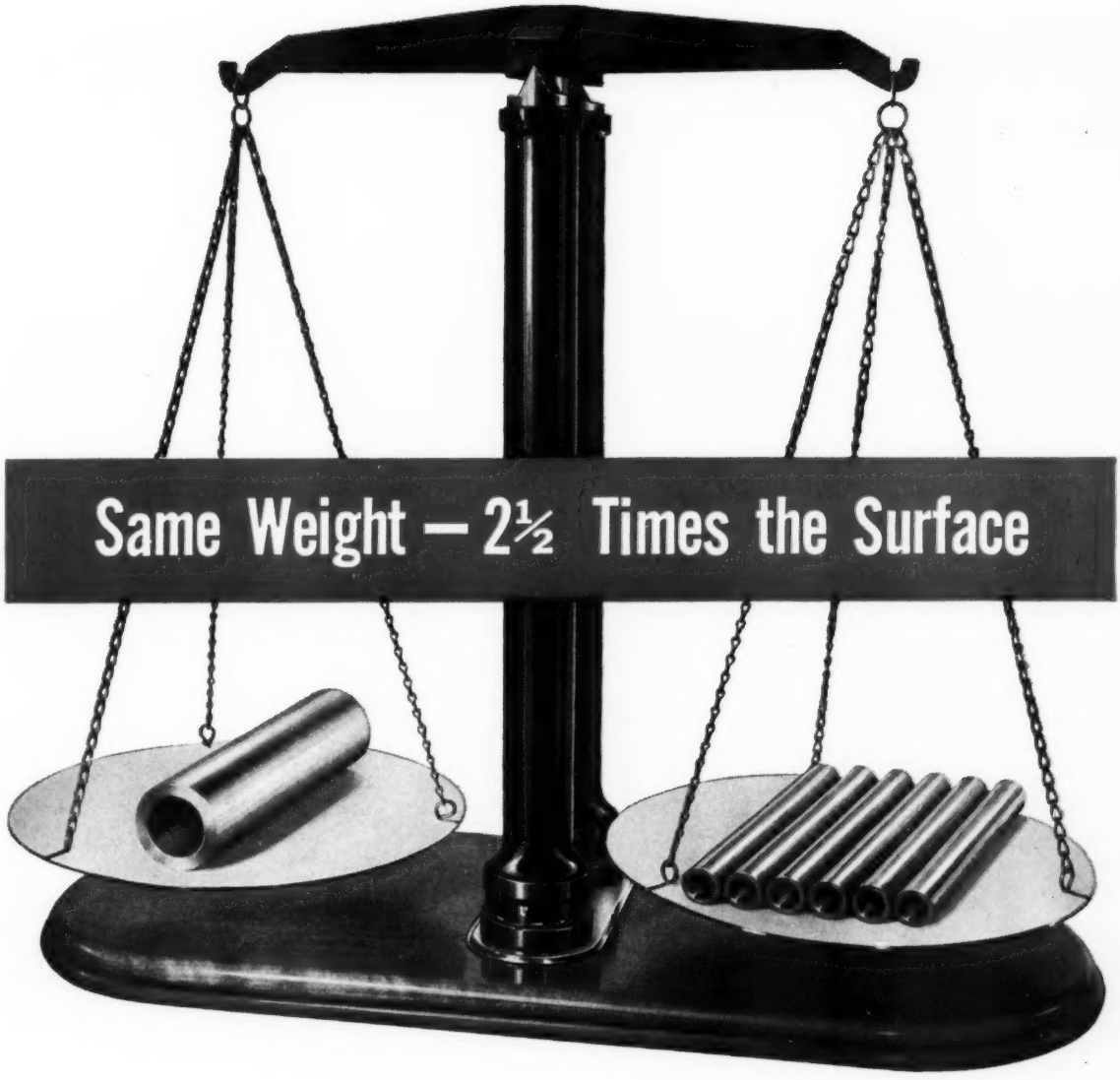
The final measure of success for any magazine, just as it is for any other product, is its usefulness to the consumer. If the magazine is to grow and prosper, it must be constantly alert to the needs, likes, and dislikes of the people whom it serves. We've been extremely fortunate because of your willingness to help. Each request we've made has been most obligingly and conscientiously answered. We've asked you for details of your engineering services; for a measure of your volume of business; for names and titles of your key men; and for your comments and criticisms. All these questions have been asked for only one reason — to help our product measure up to your demands.

Although CONSULTING ENGINEER is now less than one year old, it has already become firmly established as one of the leading magazines in the engineering field, thanks to your cooperation. And, remember, this cooperation works two ways. Whenever we can be of direct help to you, all you need do is to let us know.

Very truly yours,

M. J. Sanders

Publisher



The balance scale dramatizes one of the most important advantages of controlled circulation.

On the left side is shown a 1-foot long section of conventional tubing as used in the furnace walls of a natural circulation boiler. On the right side is shown six 1-foot long sections of tubing as used in the furnace walls of a C-E Controlled Circulation Boiler. The weight is the same but the surface area of the small tubes is 2½ times greater. Because controlled circulation permits the use of small-diameter, thin-wall tubes and provides adequate and properly proportioned flow to each circuit it affords the major advantages listed at the right.

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Exceptionally Meritorious

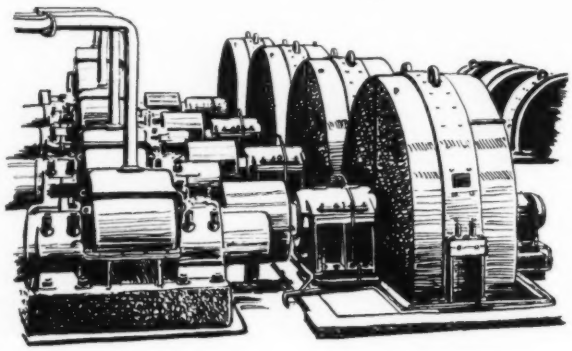
—Starts on Front Cover

most of his professional career —nearly 30 years—tackling seemingly immovable objects.

F. H. McGraw & Company builds structures, true enough — but the distinguishing feature about the firm is the variety of guts that they engineer and erect within the protecting walls and roof. The list is a recital of industrial technology.

There was the steel mill in Alabama — the company's second contract. Strike's firm designed, engineered, and built a heavy-media process coal preparation plant in Pennsylvania. They put up an aluminum rolling mill in Alabama. Strike personally supervised construction of the $31 million Jayhawk Ordnance Works (now a Spencer Chemical Co. plant) in Baxter Springs, Kansas and the $36 million Bermuda Naval Air Station.

This kind of listing could be lengthened considerably, but perhaps the point can be made just as well if we look at McGraw's current major project. F. H. McGraw & Company was awarded the Atomic Energy Commission's plant at Paducah, Kentucky. This is a $1 billion job that the company is building, aided by 2 major subcontractors and about 100 others.



Strike was born in Marion, Illinois in the heart of the down-state coal fields. His father worked for a public utility which didn't permit the family to settle down in one place for very long. He graduated from a Toledo, Ohio high school and went to work as an electrician's helper in a Toledo power house. He took a correspondence course in electrical engineering. When his father received a promotion, young Strike was enrolled in electrical engineering at the University of Illinois, where, together with his family's help and working part time, he completed his four years.

After two years, he changed to mechanical engineering, won his degree, got married to his college sweetheart, and went out to meet the world. He turned down an offer to join a newspaper chain at a figure in the $4000-$5000 bracket; the chain had admired Strike's forceful performance as business manager of the campus paper, *The Daily Illini*, which had given the local daily paper some first-rate competition.

Instead, he went with Dwight P. Robinson and Company, a New York construction firm which paid him $25 a week. Strike had decided to forget journalism and get into engineering. Inside of 90 days, he picked up his first raise — $50 a month. While at Robinson, Frank McGraw met Strike. McGraw started his own venture and six months later called Strike in to join him.

When the depression finally caught up with the firm, its staff was reduced to its lowest numbers — McGraw and Strike, plus an accountant and a secretary. They picked up some public works from states and municipalities and rode out the early Thirties. They landed a sewage disposal plant and a road-building contract. In 1934, they did work for the Bureau of Mines in Pittsburgh, and in 1935, the company got another steel mill contract which widened their experience in this field.

And they traveled wherever the jobs took them. When the Dutch Shell Company wanted a road engineered and built in New Guinea, Strike's company took the job. They went on to jobs in Panama, Paraguay, Bolivia, and Brazil. Strike now covers 100,000 miles yearly — 4 times around the world.

Strike was elected to the presidency of the company in 1941. On the strength of his record he was appointed chief of building materials, Construction, and Forestry Office of the Military Government for Germany. He was responsible for rebuilding industry and for providing housing for some 4 million homeless Germans in the United States Zone. Later he was made U. S. Deputy Chief for Reparations in that zone of operations.

In 1947, he headed a group of engineers assigned to make a field study of economic and social conditions in Japan and to outline steps which would form the basis for the country's reparations program. In June of that year, Strike became the first president of Overseas Consultants, Inc., the group of engineering and management consultants chosen for the Japanese report.

OCI signed a contract in 1948 to plan and supervise the proposed $650 million development program of the Iranian government. Implementation of that vast national development program was just getting under way when internal strife broke out in Iran, stopping further OCI operations.

Clifford S. Strike is certainly an engineer worthy of this citation: "exceptionally meritorious achievement." This is a partial quotation from the award to Strike of the Medal of Freedom; it was presented to him in 1946 by then deputy commander of the First Army, General James A. Van Fleet.

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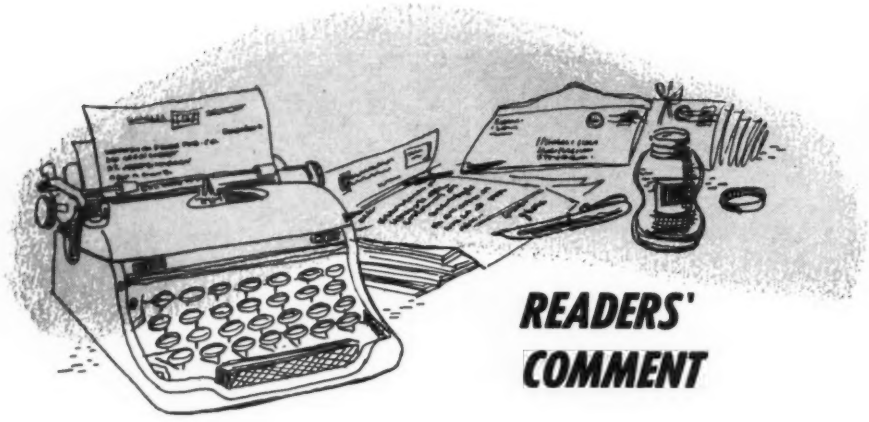

READERS' COMMENT

Engineering Status

Sir:

"Scraps and Shavings" is very good in pointing out one of the reasons doctors and lawyers have higher incomes than engineers, however, the article misses two other equally important points, namely:

1. The medical profession recognized the need for better education and raised their standards to the doctorate level. Most engineers feel that the practice of engineering requires at the most four years of very rudimentary education leading to the Bachelor of Science Degree.

2. Doctors, lawyers, pharmacists and many other groups have formed societies, which have actively supported legislation for protecting the public against quack practices. We engineers must have a national society composed of all branches of engineering with high and uniform qualification requirements, in order to develop the profession to the same plane now enjoyed by the medical and legal professions.

The engineering profession has grave responsibilities to this country, and we should stop blaming low pay on industry when the profession as a whole is unwilling to take steps to raise our standards. We have witnessed the failure of several large structures, which were designed incorrectly due to incomplete knowledge. In a small way lack of knowledge of advance theory has resulted in designs, which were too expensive, particularly in view of the shortage of materials and labor. This is the result of a smug feeling among engineers, which must be overcome before we can expect the profession to compare favorably with the medical and legal professions. We have too many people who feel that the ability to use a slide rule and a small handbook is sufficient evidence to qualify them as an engineer.

In short, we must face the fact that raising an engineer's pay does not improve his ability. Experience *per se* does not improve the engineer.

J. A. McLennan
Homewood, Alabama

Alcoa Building

Sir:

Your article in the September CE on the Alcoa Building in Pittsburgh was especially interesting. As a consulting engineering firm doing design and supervision of construction of structural, mechanical and electrical construction, we are especially interested in new materials and new ways to use materials to save construction costs.

In the case of aluminum, the problem of electrolytic corrosion between dissimilar metals, particularly aluminum and steel, and aluminum and copper, is always a problem that needs particular attention.

Would you please furnish us with complete information as to all remedial measures taken in the construction of the Alcoa Building? I refer particularly to the attachment of aluminum facing sheets fastened by bolting to steel clip angles and other places wherein aluminum was attached directly to steel. Also, reference is made to the use of aluminum in the piping system. We would particularly like to have benefit of Alcoa's water treatment research relative to the use of aluminum pipe as there are many applications wherein piping resistant to scaling and pitting will be very attractive.

Charles A. Lawler
H. E. Bovay, Jr.,
Consulting Engineers
Houston, Texas

● ALCOA IS SUPPLYING THIS INFORMATION.—ED.

References for Explosions

Sir:

In my article "Understanding Explosions" in the August issue, various facts and figures from a number of different sources in the technical literature should have been included. I feel that the publication of

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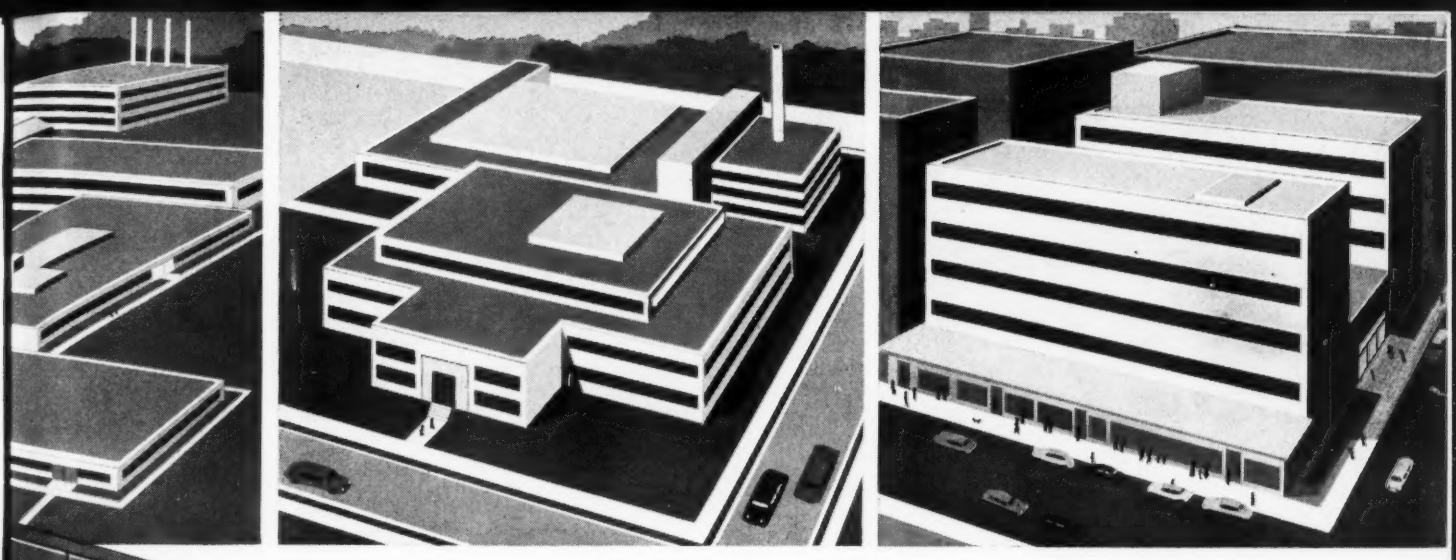

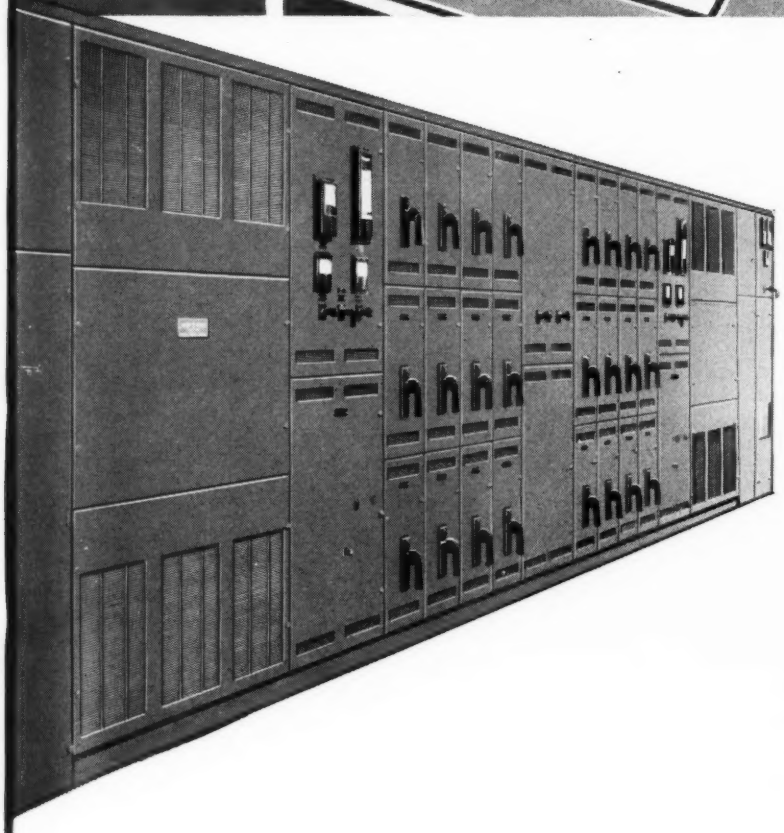

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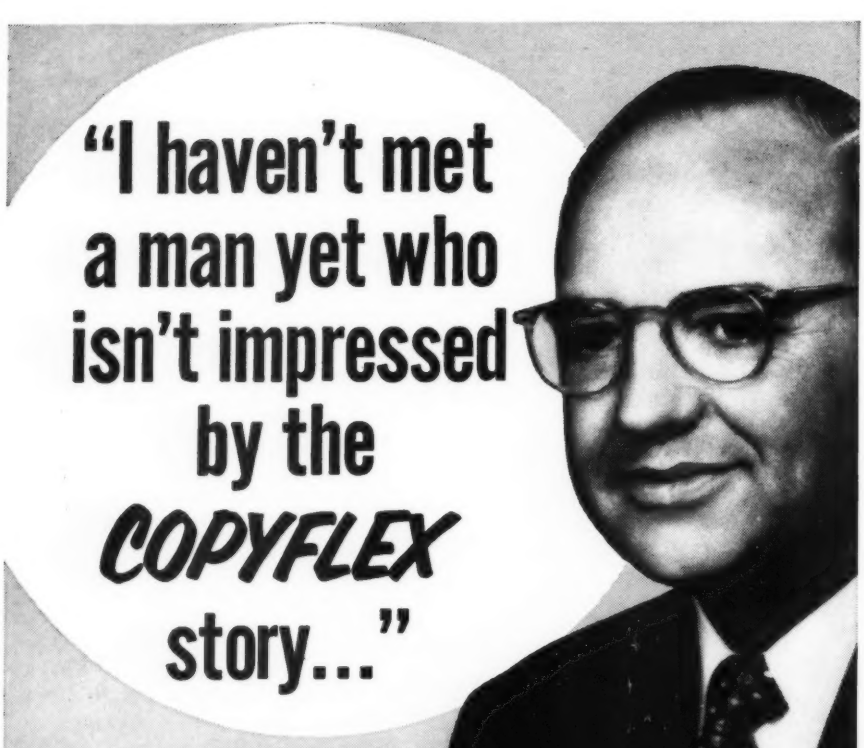

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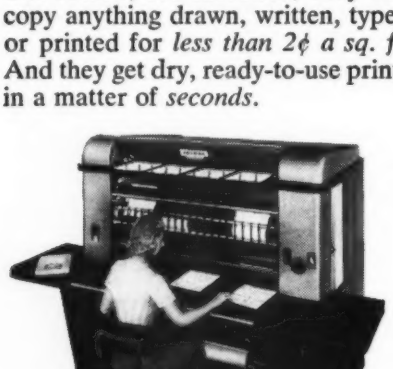

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the literature references belonging to the article will add materially to its value to the readers. For example, engineers who need to use any of the technical information will want to look up the sources of the data.

Accordingly, I am listing the references.

O. Robert Shurig
General Electric Laboratory
General Electric Company
Schenectady, New York

● SEE FULL LIST OF REFERENCES ON PAGE 78.—ED.

Free Piston Engines

Sir:

Your interesting and instructive article about free piston engines is a welcome contribution to the internal combustion engine industry.

As the accompanying bibliography does not include my book *The Modern Diesel* (Prentice-Hall, Inc., New York 1947). I call your attention to a few things in it which augment your Report.

In chapter 5 it is shown that the free piston engine is really a child of the opposed-piston engine, which was developed commercially in Germany and England before 1914 and experimentally by Secor in this country before 1900.

Also that the German Navy began equipping its submarines with Junkers free floating piston air compressors about 1934 and publicly disclosed the details early in 1935.

Illustration Fig. 32, page 45 shows a Sulzer free piston diesel compressor of an early vintage.

In chapter 19, "The Diesel as a Boiler," Fig. 161 page 206 shows 3 opposed piston, free piston diesel compressor units and Figs. 162 and 163, pages 207-208 show diagrammatically a complete 7000 bhp prime mover, including the gas-turbine units.

The free-piston diesel compressor was well known in Europe some years before Pescara obtained a U. S. patent in 1937, and long before World War II.

Your Report mentions 38% to 40% thermal efficiency which I predicted on page 101 of my book.

I do not remember any American or English book which gave as much attention to free piston developments as my *The Modern Diesel* of 1947 did until the greater interest which appeared after Commodore Small's paper at Ithaca in 1948 woke people up. On page 215, Fig. 166 I showed Small's (Then Captain) chart presented at Cleveland in 1943.

Oliver Field Allen
W. R. C. Home
Oxford, New York

11,362 square foot exterior of this laboratory erected by 5 men in 25 days with Stainless Steel Panel Construction

CORNER AND WINDOW VIEW of the Laboratory showing how effectively the two types of panels are combined in this building.

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UNITED STATES STEEL

SCRAPS & SHAVINGS

FOR SO FAR BACK as the mind of man goeth, there has been some small or great effort underway to promote a unified engineering organization to represent engineers in the same way the American Bar Association represents lawyers and the American Medical Society represents physicians. None of these efforts has come even close to fruition.

The Engineers Joint Council perhaps does represent cooperation — but hardly unification — at the very top level, and the local engineering group, in various cities may be presumed to represent some sort of unification at the "grass roots," whatever that means. However, the EJC has representation from only the technical societies, leaving the National Society of Professional Engineers standing in a corner. And in a great many cities, the local organizations are nothing more than luncheon clubs where sales "engineers" can gracefully eat with customers without having to pay for their lunch.

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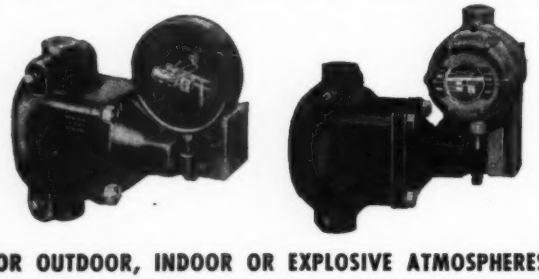

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(Write for Bulletin 39S.)

THE MERCOID CORPORATION, 4201 BELMONT AVE., CHICAGO, ILL.

Neither of these groups, top level or local, really represents the engineer. No one would seriously claim that the local societies, even those of statewide scope, represent any real step toward unification. So far as EJC is concerned, no one except the Big Mamous in the engineering societies seem to know exactly what EJC does, and agreements reached do not get down to the practicing engineer.

There are two basic barriers to genuine society unification. The first barrier is another instance of that old bugaboo "sovereignty." The officers and staff of all of the engineering societies feel, today, that they are very important men. If these societies were just branches of a unified organization, these officers would hold relatively lower offices, and the staff, to some extent, might not hold any offices at all. Also, the Founder Societies have investments and histories which they would not like to throw into the general pot.

Furthermore, many of the Founder Societies hold to a line which is theoretically straight but practically impossible to follow. They each claim that they, in themselves, constitute a Society to which all engineeers may and should belong. For example, the Civil's claim that all engineers are either civil or military, and that their organization is one to which all engineers except those in the armed services should belong. However, this argument and all arguments designed to justify a particular technical group are based on nothing more than an effort to maintain sovereignty and avoid loss of prestige in becoming a part rather than remaining a whole.

The second problem, that of membership requirements, can be solved more easily. The Founder Societies are not too far apart on this now, and ASME has just put before its members a constitutional change which will bring them more in line. But that still leaves the National Society of Professional Engineers as far away as ever. They require that all of their members be registered. The Founder Societies have no objection to registration —in fact they encourage it—but they do not include it as a membership requirement.

So if the NSPE and the Founder Societies are ever to get together—and it is essential that they do if there is to be anything resembling real unification—something has got to give. It is likely that there will be some giving on both sides, if unification ever comes so close that this is the only barrier. There is reason to believe that NSPE is willing to bend somewhat, and if the old guard of the technical societies would just bend a little, too, and in the right direction, this problem could be solved.

The discouraging aspect of the whole problem is in the fact that while the great mass of engineers in this country overwhelmingly favor unification under almost any agreement, it is the men who have been put in high office by the votes of the members who are unable to come to any agreement.

ECONOMIC NEWS NOTES

E. F. Mac Donald
INDUSTRIAL ECONOMIST

ON AGAIN — Off a couple of years ago when Bethlehem Steel turned down a bid to build a steel mill in Connecticut, New England's long-fought-for steel mill is on again with the news that the stock in New England Steel Development Corp. has been sold to a client of Ebasco Services, the consulting engineering company. It is reported that the new owner is studying anew the advisability of erecting a mill in Connecticut and has applied for a certificate of necessity for rapid amortization of a $26 million electric-furnace mill.

FAMILIAR NOTE — "Unless the free play of economic forces provides a reasonably high continuing volume of home production . . . . we may be required to resort to some means of assistance to ward off unnecessary wrenches to our entire economy." In this recent statement by Mr. Cole, Housing and Home Finance Administrator, the term "business activity" could be substituted for "home production" and we'd probably have a statement of the attitude of the Administration as it contemplates the confused business outlook. What, by the way, is a "reasonably high continuing volume" and what would be the nature and permanence of government intervention in the "free play of economic forces"?

SWEET and BITTER — Plant and equipment outlays estimated to set record high this year. **BUT** an expected fourth-quarter decline may be signaling a new trend. . . . Construction outlays have reached a new peak, about 8 percent above corresponding period last year. **BUT** in recent months contracts awarded have been lagging behind construction being completed, except for defense projects. . . . Commercial building is exceeding earlier estimates. **BUT** residential building is lagging behind this time last year. . . . .Employment is at record levels. **BUT** factory employment in August showed smallest gain over July since end of World War II. . . . Steel operations are easing. **BUT** paper industry, widely used barometer of business activity, had no summer slump and reached new high for the year last month . . . Personal income was still rising at latest report, reaching an all-time high. **BUT** farm income has been running behind 1952 . . . **In brief:** Business generally is at record levels **BUT** there's lot of talk about a downturn.

RESEARCH FUNDS — Federal outlays for scientific research and development have been running about $2 billion annually. Most of the spending is on its own installations and for services carried out in labs of industrial organizations. About 15 percent goes to nonprofit institutions, including state universities. The National Science Foundation has released the first of a series of studies relating to Government scientific activity, "Federal Funds for Scientific Research and Development at Nonprofit Institutions, 1950-51 and 1951-52," available at Supt. of Documents, Washington, D.C.

EQUIPMENT CAPACITY — The results of an interesting study of changes in the ratio of capacity to output of plant and equipment by the Machinery and Allied Products Institute "suggest that the heavy equipment installations of the postwar era have not as yet developed a condition of generally excessive capacity." Similarly, it is indicated that the increases in capacity and output since 1949 have been reasonably commensurate.

INSTRUMENTS and CONTROLS — 15,000 engineers and technicians studied $10 million worth of instruments and controls displayed by over 200 manufacturers at the annual National Instrument Conference and Exhibit in Chicago. It was the perfect setting for shop-talk about the automatic factory. Incidentally, prior to World War II, about 2 percent of plant outlays was for instruments and controls; today it is 8-10 percent and rising.

ODDS and ENDS — Nomination for quote of the year: "Everyone is for general economy and for specific spending." (remark of member of House Appropriations Committee.). . . . **Mauch Chunk, Pa.,** doesn't need any high-falutin' plan to finance acquisition of factory sites. To bolster sagging employment by attracting new industry, the townspeople, all 6,000, have pledged to kick in a nickel a week for five years. The goal—$78,000; collections first 4 months—$15,000 . . . **Univac,** the "Million-Dollar Brain" is going to work for an insurance company, the Franklin Life Insurance Co. of Springfield, Ill. The machine, which predicted Eisenhower's victory soon after early returns started coming in, can add, subtract, multiply, divide, sort, collate, merge, and tabulate, all at the same time without operator assistance. . . . Charging that slums of the future will stem from community developments laid out with a "deadly uniformity" that will make them a drug on the market, the **American Institute of Architects** and the **National Association of Home Builders** have set up a joint committee to do something about it. They feel that an industry that looks to build houses at a better-than-one-million rate for the rest of the century ought to have some better ideas on design and layout . . . A report of the **Southern Regional Congress on City Planning** (Roanoke, Va., August 1953) urged provision of data essential to industry in determining plant location even the most basic information to companies seeking favorable location sites . . . Should ***auto makers'*** optimism not be supported by favorable dealer activity, it could be a body-blow to the economy. The auto industry is reported to hold "almost unbelievably" overloaded stocks of steel . . . A new booklet to guide small business in bidding for Government contracts has been published by the **Small Business Administration. "Sound Pricing Policy in Bidding on Government Contracts"** is available at SBA field offices.

ATOMS IN ACTION

N. C. STATE REACTOR — North Carolina State, Raleigh, N.C., and the AEC have signed an agreement to make possible the operation of the first University-owned nuclear reactor. The reactor was designed and built completely with University funds. Dr. Clifford K. Beck, head of the Physics Department is in technical charge of the project. Fissionable materials to operate the reactor are being furnished by the AEC on a loan basis.

PRICES DOWN -- The price of technetium 99 is down from $35.00 per milligram to $20.00. It is doubted that this will have any substantial influence on the cost of living index.

SUDDEN ACCELERATION — Zirconium, first discovered in 1789, now used in building reactors, was not commercially produced until 1950, when Westinghouse began pilot plant operation. Early this year Carborundum Co. signed a contract with AEC to deliver 150,000 lb per year. Now, Allegheny Ludlum's Watervliet plant has a capacity for melting zirconium at the rate of 120,000 lb per year, and is planning expansion. While these figures are minute when compared with the production of more common metals, they indicate a new field for engineers, the production and application of metals recently seen only in museums and research laboratories.

BONUS EXTENDED — Still very much interested in the discovery of new sources of uranium ores in the Colorado Plateau area, the Atomic Energy Commission has extended the guaranteed minimum price schedule and the bonus payments to March 31, 1962. For eligible new mining properties, bonus payments are made on each pound of uranium oxide delivered to mills up to 10,000 lbs. Bonus payments range from $1.50 to $3.50 per pound which means a maximum bonus of $35,000. Details of payment and bonus schedules can be had from the Commission's Grand Junction Operations Office, P. O. Box 270, Grand Junction, Colo.

ATOMIC ACTIVITY—The latest "must-read" publication on atomic power development is "Hearings Before the Joint Committee on Atomic Energy." It presents the complete text of statements by 112 witnesses and correspondents —a who's who and what's what of atomic power development and private enterprise. . . . Two other comprehensive surveys of activity and developments are "Major Activities in the Atomic Energy Programs, Jan-June 1953," and "Atomic Power and Private Enterprise," Dec. 1952, Joint Committee on Atomic Energy. . . . Pointing out that if a private industry is willing to pioneer in the development of atomic power, Mr. Davidson, of the Atomic Energy Commission, stated recently that either regulatory bodies will have to formulate more flexible attitudes as to what constitutes valid risk and return for utilities, or else utilities will have to combine in such numbers for atomic development as to reduce pro-rated costs to accepted levels. Failing one or the other, Mr. Davidson said that dependence would have to be on chemical companies, makers of electrical equipment, or possibly on new organizations created specifically for the purpose of developing private application of atomic power.

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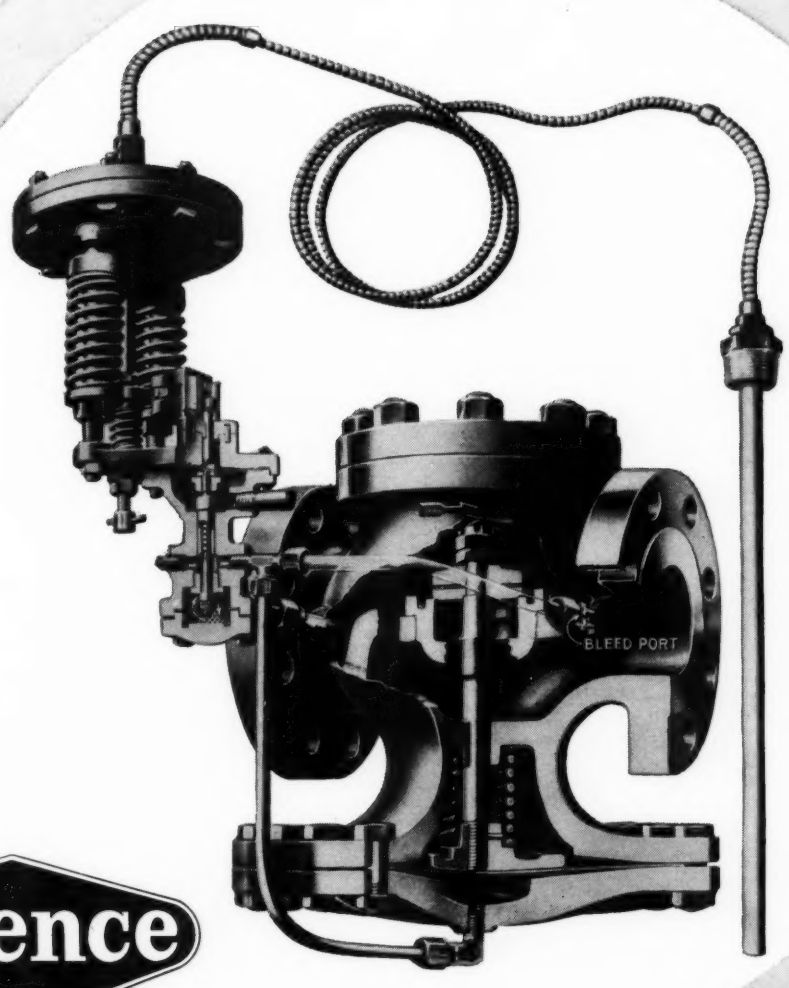

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WALDEN, NEW YORK

PIPELINE ON THE KREUZECK (RIGHT BACKGROUND) SUPPLIES WATER TO ONE DIVISION OF THE KOLBNITZ PLANT.

Hydro-Power in Austria's Alps

F. H. BAER

AUSTRIA'S potential yield of hydroelectric power is estimated at 40-billion kwh annually, based on full utilization of all available water reserves. At the present time, only 9-billion kwh are produced. However, a vast expansion program, with national and international financing, is under way to raise production of energy for international sale.

The principal characteristic of Austrian hydroelectric power production that interests engineers is the greatly varying availability of water. Because of Austria's mountainous formation, supply is concentrated in the spring and summer seasons, which extend from the beginning of April to the end of September. Water availability drops slightly in the fall, and a severe shortage for energy production develops during the winter months.

This situation has forced the Austrian, nationalized but independently operated, power enterprises to provide storage facilities for the water required during the winter months, when water is not only scarce, but the demand for electric power is higher than in any other season of the year. At the present time, Austria possesses 17 storage basins with a combined capacity of 8.7 billion gallons.

Wherever new hydroelectric power plants are under construction, the engineers try to build adequate storage facilities. One example is the system now being constructed by the Austrian Drau River Power Works Co. in the Carinthian Reisseck-Kreuzeck area. This project not only adopts the storage principle, but combines it with a pumping system which gathers water reserves during the summer months for use in the winter period.

The unique feature of the new power system is that the energy used to pump water upward into storage basins is fully recovered when the water is utilized for power production. This energy balance is possible because the ground formation at the site is

extremely favorable. Water is pumped from a level of 3638 ft to storage basins at 7810-ft elevation, but is utilized (from the 7810-ft storage level) at an elevation of 1991 ft. This feature permits the creation of 1 kwh during winter for every 1 kwh invested during the summer.

At other similar installations where water is pumped from and returned to nearly the same elevation, a given amount of water pumped for an investment of 1 kwh, later produces an average energy yield of only 0.6 kwh. Thus, the balanced operation of the new plant represents a 40-percent gain. This is of commercial importance, because higher rates are charged for electric power during the winter than during the summer. Furthermore, greater availability of electric power during periods of highest demand increases system income and permits faster investment amortization.

THE 10.6-MILLION GALLON GONDELWIESE BASIN IS PART OF THE REISSECK RUN-OF-RIVER DIVISION.

Site Characteristics

Two mountains on opposite sides of the Moell River valley furnish the water for the power system. One is the Reisseck, a gneiss-structured mountain rising 9707 ft above sea level. It is the site of four lakes and six small creeks. The other is the Kreuzeck, an 8865-ft mountain of slate and gneiss structure, which offers 11 small creeks for power production.

The power system itself is composed of four sections, the Riecken Power Plant and the three divisions of the Kolbnitz Plant. The Riecken Plant is a small, single unit station situated on the slope of the Reisseck at an elevation of 4232 ft. Its one 8000-kw Francis turbine utilizes water from several creeks and the Zandlacher storage basin, which is at a level of 5291 ft and has a capacity of 26.4-million gallons. The station produces approximately 16-million kwh annually, and operates independently from the Kolbnitz Plant.

All of the other generating facilities are in the three division Kolbnitz Power Plant, which is at 1991-ft elevation in the Moell River valley. One system, called the Reisseck run-of-river division, has two machines rated 6500 and 17,500 kw respectively. Water for these units comes from several creek systems and the 10.6-million gallon Gondelwiese basin at 4329-ft elevation on the Reisseck.

The second or Kreuzeck division of the Kolbnitz Plant is still in the projection phase. Plans call for the utilization of 11 small creeks on the Kreuzeck at 3917-ft elevation. These creeks are connected by a pipeline that forms approximately a semicircle, the center point of which feeds the 48.9-million gallon Rosswiese storage basin. Water from the reservoir will drive two, 2000-kw turbines.

The third section of the Kolbnitz Plant is known as the "storage division." This system is especially

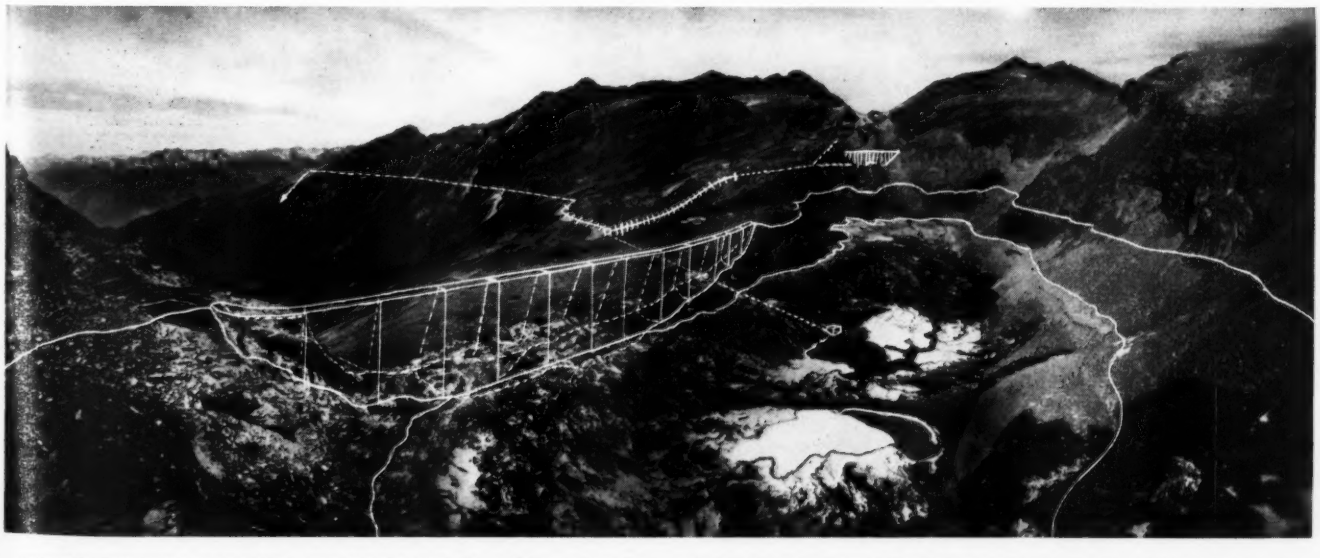


PHOTO SHOWS PROPOSED DAM LOCATIONS FOR THE LOWER (FOREGROUND) AND ONE OF THE UPPER LEVEL BASINS.

PRESSURE LINES (LEFT) ON THE REISSECK SUPPLY TWO DIVISIONS OF THE KOLBNITZ PLANT (LOWER RIGHT).

important since its potential winter capacity will nearly equal the combined outputs of the other two divisions and the Riecken Plant. Initially, it will have two, horizontal, 20,000 kw Pelton turbines. A third unit will be added when water storage facilities on the Reisseck at an elevation of 7810 ft are completed.

Storage Facilities

Four natural lakes, embedded in the gneiss formation several hundred yards below the peak of the Reisseck, will be the nucleus of the storage system. While they are only small basins at present, it was found that relatively little damming would be sufficient to greatly increase their contents. Plans prepared by the Austrian Drau River Power Works Co. in cooperation with the Austrian Grid System Co. indicate a storage volume of 4.75-billion gallons will be achieved when the project is completed. This is nearly 55 percent of the total volume in all existing Austrian storage basins.

The storage system will have two levels. Three of the lakes — High Alps Lake, Wheel Lake, and Little Lake Muehldorfer — are at approximately the same elevation and will constitute the upper level. In final form, they will contain 1.24-billion, 690-million, and 740-million gallons, respectively. All three are to be interconnected to form a communicating system for level control. The pipelines will be welded steel construction, installed underground or in tunnels.

Big Lake Muehldorfer, the fourth lake, is the lower storage level. It is about 200-ft below the other lakes, and at optional filling, will contain 2.08-billion gallons. This volume will be utilized only after the upper level has been emptied. The water will be piped to the supply line which carries the combined contents of the other three lakes. From this point, the entire storage system volume passes through an underground pipeline to the surge shaft.

When completed, the main surge shaft will be the longest direct head in the world. Extending from 7801 ft above sea level to the 1991-ft elevation of the Kolbnitz Plant within a total length of 2.671 miles, it provides a net level difference of 5810 ft. The resultant pressure of slightly over 2500 psi at the power plant will be the greatest free-falling, artificial water force achieved to date.

To withstand this pressure, the lower section of the high pressure pipeline (diameter decreases from 55.1 in. in the upper section to 37.4 in. in the lower part) is made of seamless steel pipe. Wall thickness is 1.38 in., and to add strength, the pipe is surrounded by a steel band 2.76 in. thick. Design flow rate of the

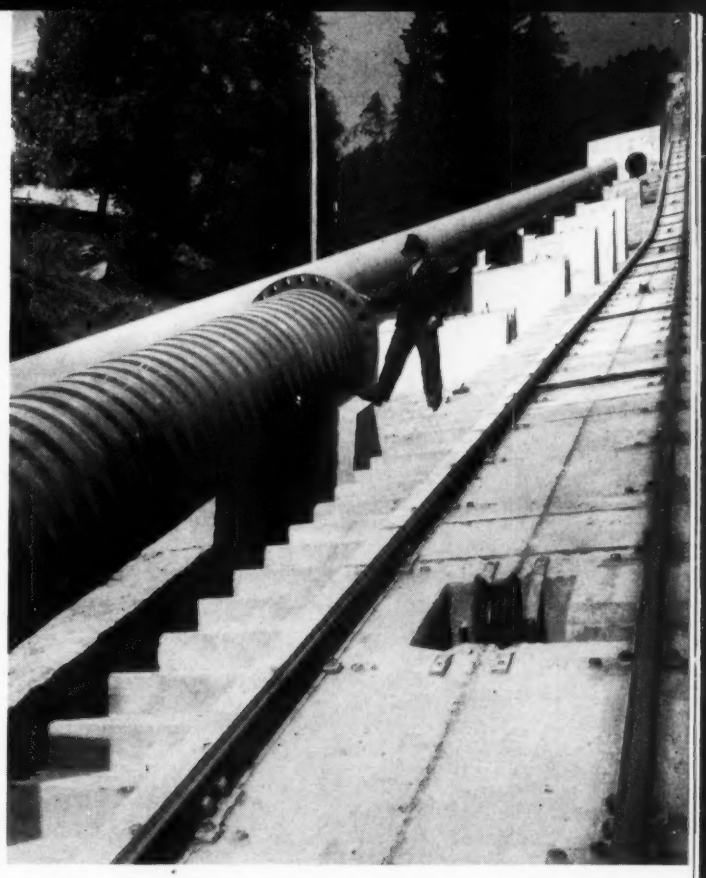
surge shaft is approximately 1200 gps. Sections of the pipeline were made by Tubi-Togni, an Italian concern specializing in this field.

While the head of 5810 ft is unique in itself, the engineers at the project feel that an even greater feature is the pumping system. Water collected from the creeks which serve the run-of-river division can either be utilized immediately at the Kolbnitz Power Plant or be pumped upward to the storage basins. Pumping will be done during the summer months, when electric demand is low and water supply is at peak level. The water required to produce the estimated 27-million kwh which are necessary to fill all four reservoirs would otherwise be forced to flow downwards without driving the turbines.

Pumping Station

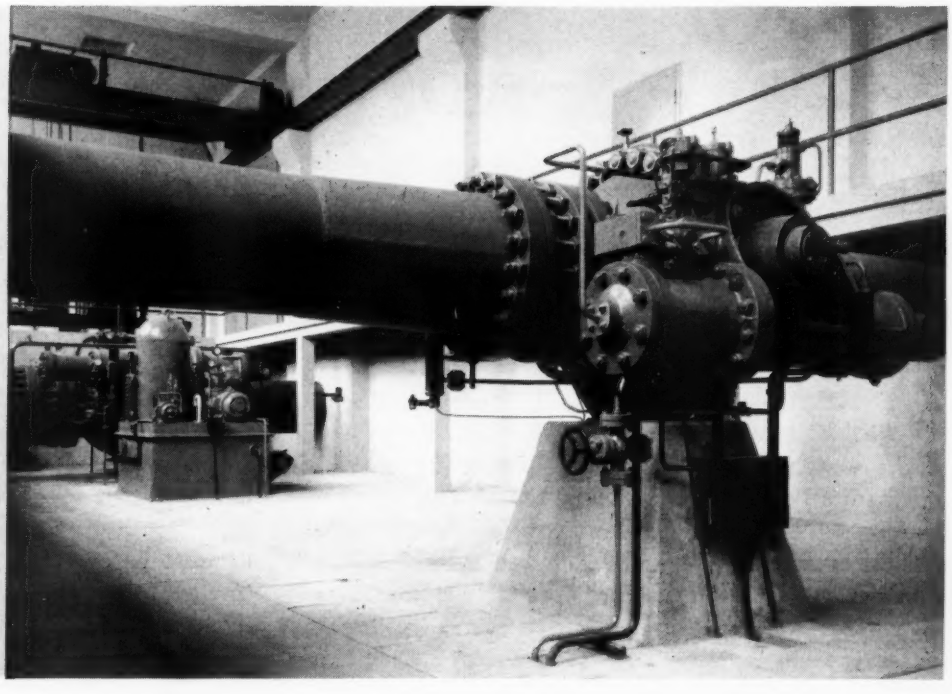
The pumping station, located at 3638-ft elevation on the Reisseck, is equipped with two Swiss pumps. These units are designed to elevate the water 4172 ft to the 7810-ft storage level at a rate equivalent to the full capacity of the surge shaft. The water from the main pumping line is first passed to the three interconnected basins in the upper storage system and then to the single reservoir at the lower level.

Since Austrian-produced electric power is an ever increasing item in international trade (mainly to France, Western Germany, and Italy), it plays an important role in the reconditioning and further development of the over-all Austrian economy. Thus, the Austrian Drau River Power Works Co. has applied to the World Bank for a credit to build the necessary storage basins. The granting of such an investment loan is seen as a sure way of raising the economic and political strength of this small country half behind the Iron Curtain.



LOWER SECTION OF STORAGE SYSTEM SURGE SHAFT IS SEAMLESS PIPE, REINFORCED WITH STEEL BANDS.

From the technical viewpoint, experts say the project offers maximum possibilities because of the relative locations of water supplies, power plants, pumping station, and pipelines. That the highest head in the world is to be built in Austria is not too important to the projecting engineers. They believe the balance in output and investment of power constitutes the principal achievement.



THESE VALVE SYSTEMS IN THE KOLBNITZ PLANT ARE USED TO REGULATE WATER FLOW RATES TO THE 6500 AND 17,500 KW UNITS IN THE COMPLETED REISSECK RUN-OF-RIVER DIVISION.

Contractors and Consultants

HENRY E. BATON, JR.
President, Baton Construction Corporation

Henry E. Baton, Jr. received his degree in civil engineering from Yale University in 1931. He joined the Baton Construction Corporation in 1934; during his work with the firm he gained wide experience in the construction business. He entered the armed forces in 1942, rising to colonel in the Ninth Air Force. He assumed presidency of the Baton firm shortly after his return in 1945. He is a member of the Pennsylvania State Council of Building Contractors, the Yale Club, and the T-Square Club of Philadelphia.

ANY CONSULTING ENGINEER can offer "turnkey" services if he selects a contractor at the earliest stage of a project and uses him as the engineer's "construction department." The specialized experience of the competitive general contractor has never been used to the fullest extent and has seldom been used in more than a minimum way. This statement is made as a result of recent experience in working as part of the architect and the engineer organizations, both having specialized knowledge of industrial design.

The principal sales argument of competing design and construction firms seemed to be that under their type of contract, the client could get undivided responsibility for the entire project. This important advantage to the client can also be realized, however, with separate organizations who join forces on a project. In addition, several other

advantages not otherwise possible can develop.

There are specialties in construction, just as in any other field. Our organization, for example, has built more research laboratories than any other firm in this area. It was on the basis of this background and on the specialized experience of the engineers and architects with whom we collaborated that a combined team was given a recent assignment.

The owners of the project, who have had experience with design and construction organizations, have said, "We like the combination of specialists." And they have selected this combination of specialists instead of taking one, packaged organization—all parts of which might not have fitted their specific needs. They independently selected and assembled these specialists from a large group of architects, engineers, and builders. They made up the team from groups having experience in the specialties they required, and they gained the benefits of independent thinking among the specialists.

New Techniques

New ideas must have a practical test. In the construction field, no one is better qualified to give them a practical test than the competitive construction organization. Unfortunately, the accusations that many construction firms have refused to keep in step with modern practices are in many instances too true. But at the same time, the progressive construction firm has had a chance to try many new techniques on its own that have met the engineers' specifications and have still saved money on the project.

Working together with the engineer and architect, the contractor's experience — practical experience gained in the field—can be put to work in the design stage. Here it can help to realize even greater savings than if the contractor's ingenuity is left untapped until these problems are met by him in the field, after the design is complete and fixed.

Eliminate Policing

The day has passed when the architect or the engineer must act as a policeman, guarding the owner's interest against the builder who is out to short-cut specifications to make a quick dollar. Today's responsible construction firms, staffed by professional engineers, can represent the owner's interest to the same degree as the engineer, particularly when the two are working together on a professional basis to meet the individual needs of the project.

In a new 106,000 square-foot electronic research center for the Burroughs Adding Machine Company currently being built in Paoli, Pa., the owner selected the builders at the same time they selected the engineers and architects. This selection was made after a review of many combinations of engineers, architects, and general contractors. All worked together as one organization through all the phases of design and construction. Construction started as soon as foundation and grading plans were complete. The engineers and architects, working with the owner's design team, completed the plans in a smoothly arranged sequence.

Construction Department

The builders served as a "construction department" for the consulting engineer from the earliest stages of preliminary planning. Each research laboratory the builder had been associated with in the past produces new methods and experiences which were drawn upon in planning and building the Burroughs project.

To accomplish the desired modular design as economically as possible, the consulting engineer was advised on pertinent matters concerning construction costs. Consideration of the most economical structural framework arrangements enabled the engineer to determine module dimensions which would take full advantage of these economies and still meet all other building requirements.

Though a structural steel building was decided upon as best for this occupancy, it was evident that sufficient steel for the entire project would not be immediately available. Construction was started as soon as plans for the foundation were completed. Reinforced concrete construction was used for all work up to and including the ground floor slab of the laboratory and for the administration sections of the building. In this way, it was possible to meet the owner's urgent need for occupancy.

Savings Result

The owner as well as the engineer realized substantial savings in time and in costs. In addition, problems of cost checking were largely eliminated. The builder's estimating department experienced in working out large competitive lump-sum bids, was able to evaluate alternate designs quickly and to protect the engineer and owner from the use of impractical devices and materials.

The engineer gained full advantage of the experience which the builder's staff had accumulated in many research laboratory projects. The consulting engineer's facilities were, in effect, considerably expanded without additions to his payroll. He worked directly with the owner's engineering department in developing the project requirements with the knowledge that his services were complete for all phases of the job.

To meet the competition of design and construction organizations, the client should select the contractor as soon as he has appointed the engineers. The contractor should be free to work fully in developing the most effective and efficient construction in terms of speed and finished result.

The Optimum Boiler Water

DR. EVERETT P. PARTRIDGE
Director
Hall Laboratories, Inc.

Dr. Everett P. Partridge studied chemical engineering at Syracuse University and at the University of Michigan, where he received his Ph.D. in 1928. He has been active in the field of industrial water for more than a quarter of a century, serving as director of research at Hall Laboratories, Inc. for 15 years before becoming director of that organization in 1950. At the present time, Dr. Partridge is chairman of the Joint Research Committee on Boiler Feedwater Studies, chairman of the chemical section of the ASME Code Subcommittee on Care of Power Boilers, and a member of both the ASTM Committee D-19 on Industrial Water and the Inter-Society Corrosion Committee. His many technical papers include; studies on formation of boiler scale, corrosion and cracking of metals, stabilization of cooling water, solubility equilibria at high temperatures and pressures, and the properties and uses of the complex phosphates for water treatment.

Dr. Partridge originally prepared the article "The Optimum Boiler Water: A Continuing Problem in Chemical Engineering Design" for presentation at the Fourth International Congress on Industrial Heating held in Paris, France during October 1952. This information was abstracted from the official proceedings of the Conference.

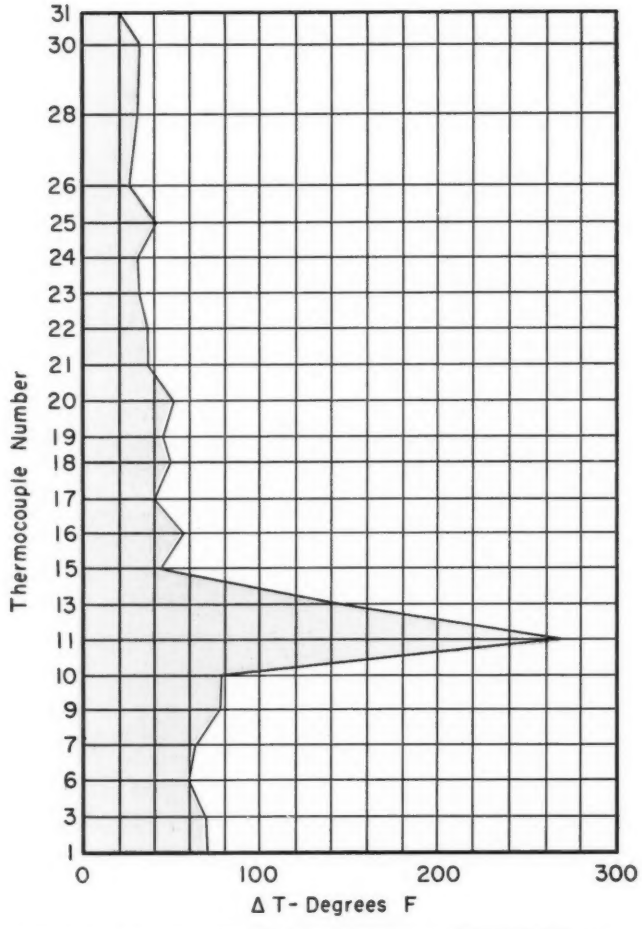


FIG. 1—AN ABNORMAL TEMPERATURE DIFFERENTIAL ACROSS A BOILER TUBE INDICATES FILM BOILING.

MECHANICAL ENGINEERS sometimes assume that two boilers, designed alike and built to the same physical specifications, are identical twins which will behave alike. What could be more satisfactory, they might think, than to supply each of these identical boilers with an identical boiler water precisely described in some international standard specification prepared for that purpose?

Perhaps this could turn out in practice if each boiler was fired in an identical manner with identical fuel, producing identical patterns of slag on the furnace walls, and steam was generated at identical rates on an identical load curve. Even then simple economics might still forbid supplying these boilers with an identical boiler water if they were in localities where the available raw waters differed greatly in composition.

Actually, these assumptions are very rarely true. Even boilers of the same design in the same station supplied with the same fuel and the same feedwater frequently experience trouble to quite different degrees. It is just as if one twin of an identical human pair were to develop appendicitis while the other did not. When consideration is extended from boilers which are supposed to be the same to the endless variety of differences in design and in

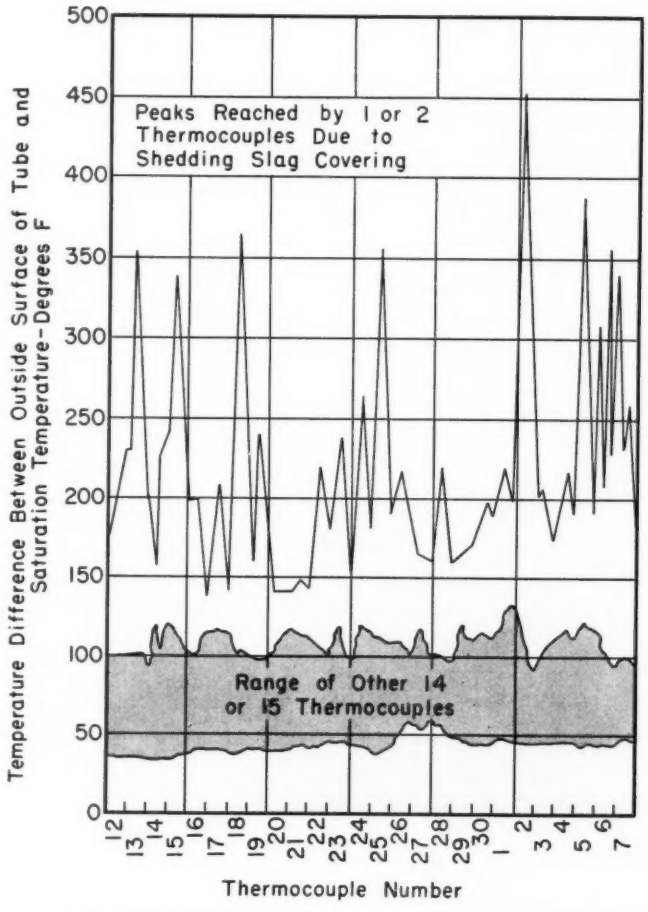

Peaks Reached by 1 or 2 Thermocouples Due to Shedding Slag Covering
Range of Other 14 or 15 Thermocouples
Temperature Difference Between Outside Surface of Tube and Saturation Temperature-Degrees F
Thermocouple Number
500
450
400
350
300
250
200
150
100
50
0
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7

FIG. 2—DEVELOPMENT OF A STEAM BLANKET INSIDE TUBE WAS PROBABLY CAUSED BY SHEDDING OF SLAG.

conditions of operation which are met in practice, then the concept of one standard boiler water appears thoroughly impractical. Experience teaches that boiler water must be designed for the boiler.

Steel cannot be fabricated into a boiler nor can the boiler function to transfer heat to boil water without setting up stresses in the steel. Thus, stress as well as heat transfer and temperature is involved in a close and complex way with the chemical reaction of corrosion which always tends to occur whenever steel and water are in contact. As for circulation of the water which cools the steel of the boiler tubes, not only the mass flow of fluid, but the pattern of the water and steam in the mixture is an important consideration.

Conditions at the Interface

The relationship between flow of heat through the tube wall and flow of water within the tube at different places in the same boiler has been the subject of much earnest study and vigorous discussion during the past decade. Two phenomena of special importance are film boiling, characterized by the local formation of a continuous layer of steam on a surface subjected to a high rate of heat transfer, and the concentrating film of solution developed to some degree on any surface where boiling of the fluid takes place.

Film Boiling

In 1943, evidence[1] of film boiling was reported in the lower part of an experimental vertical tube installed in the wall of a boiler furnace at the Kips Bay Station of Consolidated Edison Co. of New York. During this test, which was conducted at 2000 psig, a mixture of 82 percent of water and 18 percent of steam by weight was pumped upward through the tube at the rate of 99 lb per sec per sq ft of internal tube area. The internal and external diameters of the tube were 0.92 and 1.25 in. Based on the projected area of the tube, the average rate of heat absorption over the length of 52 ft was 73,000 Btu per sq ft per hr. At the upper end of the tube, a mixture containing 70 percent of steam by weight was discharged at a velocity of 14 fps.

Thermocouples located 16 and 18 ft up the tube showed high and fluctuating temperatures in comparison with those above and below. The average values at this "hot spot" are shown in Fig. 1. Other tests with similar rates of heat input but with a higher water flow rate through the tube showed no unusually high temperatures.

Film boiling must be considered as the probable cause of failure where wall tubes, substantially free of scale and sludge, show damage by overheating in the region exposed to the greatest radiation.

As a form of steam blanketing, film boiling may cause various types of damage[2]. The water and steam oxidize the hot steel to black magnetic iron oxide. If this oxide is removed by mechanical action or chemical attack, the internal surface of the tube along the side toward the furnace may be grooved or deeply pitted. On the other hand, the tube may suddenly blister and draw out to a thin-edged rupture. Or repeated cycles of establishing a vapor film with consequent overheating followed by collapse of the film with resultant quenching by the relatively cool water may cause brittle, thick-edged fractures[3] in the tube wall.

Since 1943, the number of published cases of tube failures which could be ascribed definitely to film boiling has been small. One interesting example[4] may have occurred during the early operation of the 2500 psig natural circulation boiler at the Twin Branch Station of the Indiana and Michigan Electric Co. As shown in Fig. 2, thermocouples attached to the external surface of partially studded tubes would show sudden increases in temperature. These would range up to 350 to 450 F above the saturation value of 629 F corresponding to a temporarily reduced operating pressure of 1750 psig.

Such fluctuations in temperature must have been caused by changes in the radiation to the boiler tubes so large as to seem impossible, by variations in the supply of water to the tubes so great as to

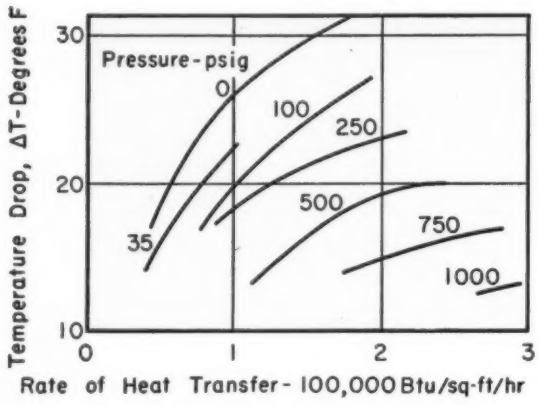


FIG. 3 — OPERATING CONDITIONS AFFECT THE STEEL TO WATER TEMPERATURE DROP.

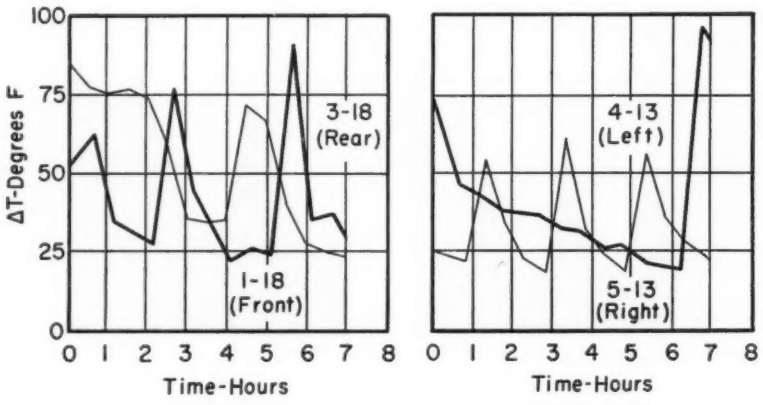


FIG. 4—HEAT TRANSFER DECREASES WHEN SPONGE ASH FORMS ON THE TUBES; INCREASES WHEN THE ASH COATING DROPS OFF.

seem improbable (because of the generous provision for good circulation), or by film boiling.

Examination of two tubes in the first division wall which failed by cracking longitudinally yielded further evidence suggesting film boiling. In this unit, the furnace is fired from the top. The vertical first division wall separating the primary furnace from the first open pass is comprised partly of studded tubes with their face toward the furnace. Prior to the failures, alternate tubes had been removed at each side of the division wall, allowing furnace gas to short-circuit directly past the remaining tubes. The failures occurred in the first widely spaced tube at each side of the solid wall, about 10 ft from the roof of the furnace, where the tubes would be subjected to intense radiation from the burners.

The cracks were of the thick-edged type, the second one tearing open for a total of 7 inches. The microstructure of the outer surface of the tube indicated that its temperature had been as high as 1600 F. Inside the tube, iron oxide was evident over a small area around the rupture. Since continuous overheating would have caused a knife-edged failure on an obvious blister, it seems probable[5] that a limited area was repeatedly overheated by development of a steam film and then quenched by contact with water as the film collapsed.

Another report[6] of blistering and failure in the vertical tube of an experimental boiler indicates film boiling was responsible for damage after 60 days of operation. It was estimated that, in the lower half of the tube where failure occurred, the heat absorption was 50 percent higher than the average heat absorption of the complete unit. Analyses of material from the internal surfaces showed values for iron, sodium, and phosphate which would today be regarded as good evidence that sodium iron phosphate had been formed in conjunction with iron oxide.

Loss of ash deposit from the surface of a wall tube has been blamed[7] for some of the failures from overheating and blistering observed in practice. Although not specifically mentioned, film boiling might develop as a result of increase locally in an already high rate of heat input.

The Concentrating Film

While film boiling may develop only in a few places in a few boilers, "concentrating film"[8] is a universal feature of all boilers. Inevitably, whenever a bubble of steam is formed, whatever was present in solution in the water before vaporization must tend to be concentrated in the remaining water. The higher the rate at which boiling takes place, the greater the tendency to accumulate dissolved substances in the film of water next to the heat transfer surface where the bubbles originate. As long as heat is flowing from this metal surface to the water and the water is being converted to steam, the concentrating film continually is being built up.

Opposing this accumulation of dissolved substances is the rinsing action of the water not vaporized as it flows turbulently past the heat transfer surface. If this surface is free of any porous deposit or product of corrosion and if water is circulating at a high rate, the rinsing action may keep the concentration in the film to a low value. Otherwise, dissolved substances may accumulate until sodium sulfate or sodium phosphate actually will be deposited as solids, producing the condition known as "hideout." At the same time, very soluble substances such as sodium hydroxide may concentrate until the strong solution is capable of attacking the hot steel. A start has been made toward providing some of the fundamental physical-chemical data[9] necessary to predict what may actually occur in the concentrating film.

One comprehensive picture of the manner in which the absorption of heat by furnace walls may change is contained in a report on tests at Tidd Station[10]. This shows how the temperature of the outside of the wall tubes varied from point to point during operation of a tangentially fired furnace. As might be expected, the pattern changed profoundly

when the position of the flame was varied by tilting the burners upward or downward. Rate of steaming and accumulation of ash on the wall tubes also affected the pattern markedly. Variations in the amount of excess air were influential to a lesser but still significant extent.

Studies [11] indicate that the temperature drop from steel to water boiling under various pressures decreases with pressure and increases with rate of heat transfer as shown in Fig. 3. For a boiler such as the one investigated at Tidd Station, operating at 1375 psig, the temperature drop across the boiling film at the surface of the tube would be of the order of 5 F, assuming that the internal surface was practically free of deposit. Subtracting 5 F from a total temperature drop of 100 F measured at some points during a test at rated capacity would

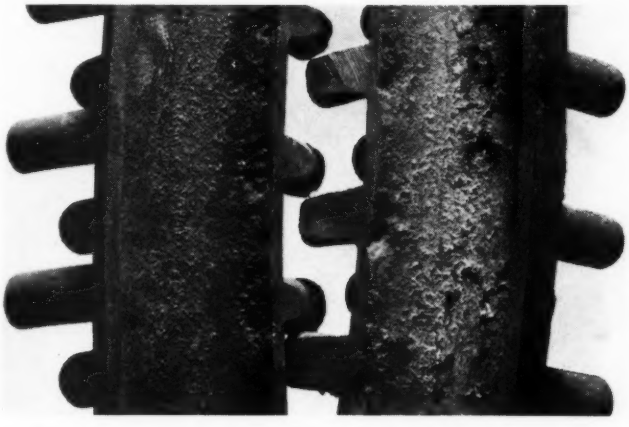


FIG. 5—LOCALIZED ATTACK ON INTERNAL SURFACE BENEATH STUDS SPOT-WELDED ON OUTSIDE SURFACE.

leave 95 F for the temperature drop through the steel wall of the boiler tube. Since this wall would average 0.3 in. thick, and its thermal conductivity would be about 29 Btu per sq ft per hr per deg F per ft of thickness, the rate of heat flow through the wall of the tube would be 110, 200 Btu per sq ft per hr, a value moderately, but not excessively, high.

During later test runs at maximum capacity, much higher values were observed for the total temperature drop, one thermocouple registering average values of 199, 192, and 193 F over test periods of 2½ to 3 hr. Using a value of 195 F for calculation and allowing a liberally higher value of 10 F for the temperature drop across the film of boiling water, the local rate of heat transfer for these tests attained a value of approximately 215,000 Btu per sq ft per hr. A subsequent test period of 5 hr when the boiler was operating at about 87 percent of normal rating, however, produced an average temperature drop of only 78 F.

The effect of sponge ash upon heat input was shown to be very considerable. Total temperature drop just above the burner zone in one test varied from as low as 20 to 25 F when ash had accumulated on the tubes to as high as 90 to 95 F when it had fallen off. Furthermore, cyclic variation was observed, the period differing with the location of the tube as shown in Fig. 4. What effect such local variation in heat absorption of closely spaced bare tube walls adjacent to the burners in a dry ash furnace may have upon fluid flow within a tube is a matter for speculation. Certainly, the changes in heat input to a tube surface tend to produce changes both in the local stresses in the steel and in the content of dissolved solids in the concentrating film.

A temperature drop across a concentrating film must mean an elevation in temperature of the film of solution next to the heat transfer surface. It may seem surprising but it must follow that if this film is only 5 F hotter than the body of the boiler water, the concentration of dissolved substance in the film must be measured in percent rather than in parts per million. In fact, the concentrating film probably plays a prominent role in forming deposits and producing corrosion[12],[13] on heat transfer surfaces in many instances. Often such conditions are blamed upon small residual concentrations of dissolved oxygen in the feed as a convenient whipping-boy.

When reference is made to designing a boiler water, what boiler water is meant? Is it the water in the drum where steam is being separated from and feedwater is being mixed with the turbulent discharge from many tubes? Is it the water in the downcomers on its way to the distributing headers? Is it the water passing a field weld in a wall tube? Or is it the water in the concentrating film on the ceiling of an inclined screen tube? If there is an optimum composition of a boiler water, then at which point in the boiler is it most necessary to provide this optimum composition?

The practical answer is that the boiler water must be designed to give the best possible protection to that portion of the boiler which is most vulnerable to water damage. At the same time, the medicine to cure or to prevent an infection in one part of the system must not produce an allergy in another. Almost every chemical used in conditioning boiler water, like almost every drug used in treating human disease, can kill as well as cure.

Good and Bad Effects

Scientifically controlled phosphate conditioning[14] has been a highly successful method for preventing hard calcium sulfate and calcium silicate scale formation on boiler tubes for over 25 yr. As a corollary of the great general good accomplished by phosphate conditioning, however, there may follow the evil (much less serious but still an evil) of accumulation of calcium phosphate sludge in the portion of the boiler circuit immediately beyond

(Continued on page 68)

CONTACT BETWEEN THE TECHNICAL PUBLICITY DEPARTMENT AND THE BLUEPRINT ROOM IS IMPORTANT AS A MEANS OF OBTAINING DATA FOR TECHNICAL ARTICLES.

Three Aims of Technical Publicity

EUGENE F. GIBBONS
Designers for Industry, Inc.

Before beginning your technical publicity campaign, it is necessary to understand its true aims. By long-range planning, engineering firms can gain the desired types of publicity.

BEFORE A TECHNICAL PUBLICITY campaign can be established, it is necessary to define technical publicity and to understand its true aims. Once this is done, the campaign can be confined to certain boundaries, and any action or matter which falls outside the scope of the definition can be rejected as having no place in the program.

A good definition for "technical publicity" is: Any action or matter, especially appropriate to any art, science, business or the like, which is spoken, written, or printed to secure public attention; also the attention so gained. Once an engineering organization has this definition firmly ingrained, it can concentrate on its technical publicity campaign.

An effective campaign should be threefold in its

AN UP-TO-DATE TECHNICAL LIBRARY SERVES AS A VALUABLE SOURCE OF BACKGROUND MATERIAL FOR TECHNICAL ARTICLES, AS WELL AS A SOURCE OF DATA ON THE LATEST ENGINEERING DEVELOPMENTS AND PROJECTS.

goals — it should achieve maximum prestige in the eyes of the engineering profession, it should obtain sales impact by establishing and maintaining client relationships, and it should maintain sound internal and external relations. Each goal is important, and one cannot be considered of more importance than the other two.

Typical Campaign

As an example of how established principles can be used to realize these three objectives, the technical publicity department of our firm recently aided one of its clients, an appliance manufacturer, on a publicity program which practically doubled the manufacturer's market potential for 1953. As a result, future satisfactory relations with this client are practically assured. Certain prestige value also was obtained for our organization by calling attention to the fact that we designed and engineered the new unit.

This was achieved by placing technical articles on the appliance design in two engineering journals. A feature article was written for the public via a local paper and thereby gained community recognition for the local organization. Our engineering personnel also were given reason to pride themselves in the fact that they helped design and engineer the technical details of this appliance, and that they received recognition for it. Altogether, the technical publicity department placed features in seven publications. Six of these publications have nationwide circulation.

Each article was written within the confines of the definition of technical publicity. Stories were placed only in those publications from which the most good could be derived, both for the client and for our own organization. Articles were not placed merely on the basis of "copy for copy's sake" — if this procedure had been followed, probably double the column inches could have been obtained. However this would have been outside the limits of the definition since it would not have been appropriate to our science or to our business. Dignity in the campaign was maintained, and our diligence was well rewarded.

Another type of publicity material which improved

our firm's stature in the profession included technical articles on an electrical duelling indicator and high frequency propagation. Feature articles were written to show the advantages of intelligent redesign, and to tell how a consulting development organization aids its clients.

Personnel announcements added to the firm's prestige by showing the diversified experiences of these people to the public and the profession. One of the executive group participated in a local radio station discussion on the advantages and disadvantages of processing new products to add to an organization's present product lines.

"Letters to the Editors" provided additional publicity, but letters were only placed on subjects pertinent to our line of business.

In cooperation with the sales department, the technical publicity department released a series of brochures to reader inquiry departments of technical magazines. This resulted in well over 100 replies from potential clients.

Procedure

The mechanics involved in releasing this material are elementary, but essential. The technical publicist submits his material with a definite plan of action. As in any matter involving the obtaining of approval, the best chance for success lies in the offering. A group of facts does not constitute a plan of action. The plan results from a solid analysis of the problem, and from suggesting that plan to management. Ordinarily, management approval is practically automatic if company policies are followed and a suggested course of action is submitted.

Management should have the last word with respect to approval. A national publication recently reported that 94 percent of all publicity from U. S. concerns is passed on by top management.

The company's technical publicist is the one who puts the plan into execution. He should be trained in the art and science of technical writing. He should sift technical material, scan the field for new ideas, help to cement solid client relationships, and instill a fervent engineering interest in company personnel. Above all, he should believe in technical publicity and its goals. Clippings and column inches will take care of themselves if the technical publicist concentrates on the one true purpose — engineering integrity for his company.

To be successful, the technical publicist must determine just how far to go on any particular program. However, he should feel completely free to ask the help of anyone in the organization in his endeavors.

Technical Writing

Among the varied and vital functions of the technical publicity department is that of rendering assistance in the improvement of internal relations programs. As an example, our technical publicity department has contributed to the betterment of internal relations within the company by initiating a technical writing program. Engineering personnel are encouraged to write technical articles and submit them to management. If management approves an article, the author is rewarded with a $25 bonus from the company. The technical publicity department then places the article in an appropriate technical journal. When it is accepted for publication, the company rewards the author with another $25 bonus. The engineer-author is also entitled to any remuneration the journal wishes to pay for his manuscript.

For the first half of 1953, the department placed three articles submitted in this program. Although one of these articles was not directly related to the company's regular business, it was so well written and illustrated that the technical publicity department submitted it to the editor of the local Sunday pictorial. He liked the article well enough to give it a two-page pictorial spread. It was later published in a national technical journal. Thus, a subject of importance to the engineering profession but unrelated to the company's regular business was utilized for the mutual benefit of employee and employer.

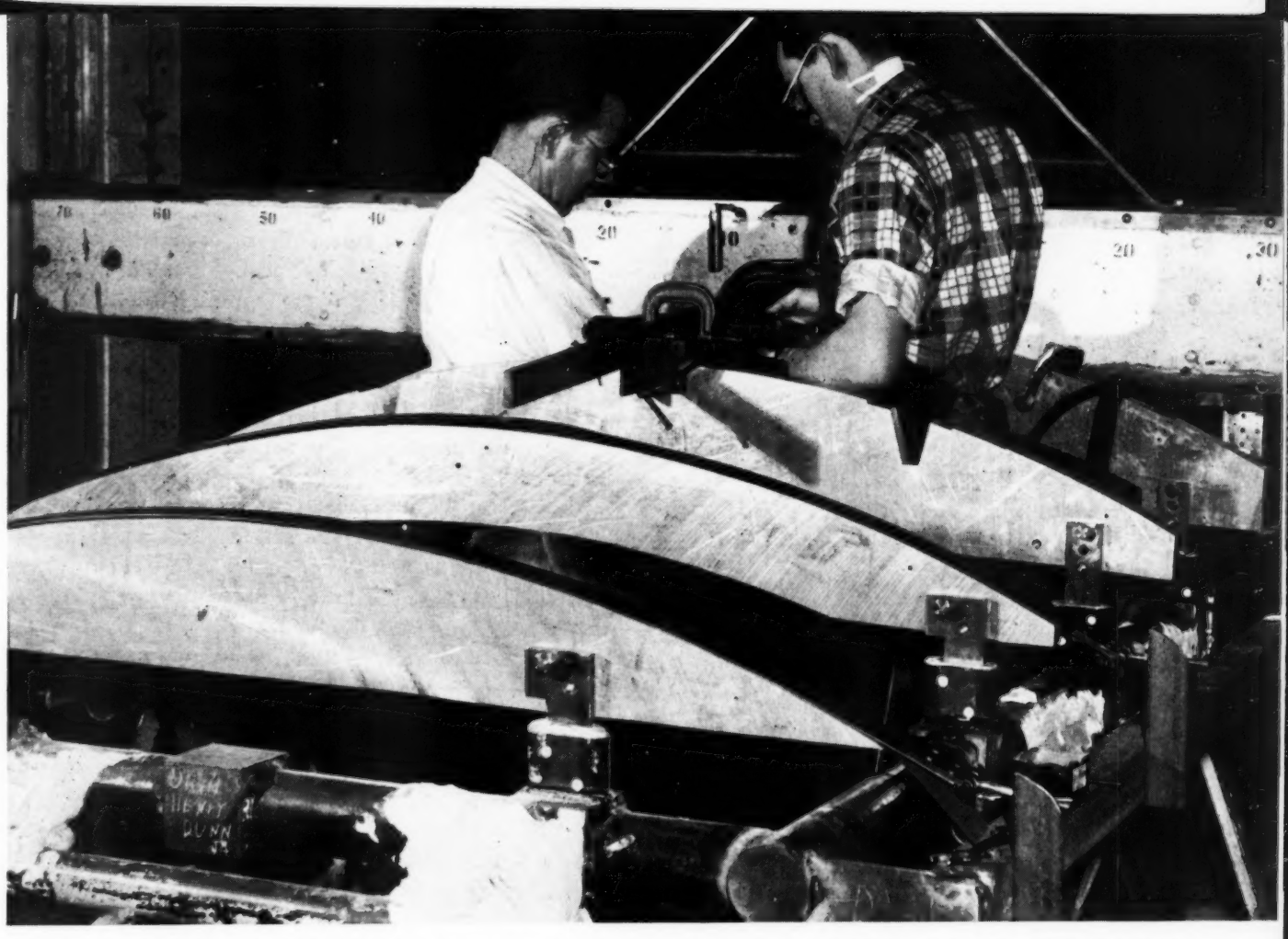
Additional Functions

Another of the vital functions that receives considerable attention by the technical publicity department is its activity in encouraging company personnel to participate in local engineering society meetings. It is one of the company's chief aims to instill a pride of the engineering profession in its personnel — for "professionality" is the heart of the consulting business. In addition, by associating with engineers from all industries at local engineering meetings, publicity coverage is spread even further.

Besides promoting company activities, technical publicity can be aimed at advancing the engineering profession. A program based on the true aims of technical publicity can definitely help to raise the engineering profession to the standards we desire.

The accomplishments of technical publicity, however, cannot be measured in column inches of print. It can only be measured in the degree in which established goals are reached. If two hundred column inches of print are required, it would be proper to establish this as a goal. But to place fifty stories when one would do the job is a waste of time, energy, and money.

Established goals are best achieved by long-range planning. Such planning will help to avoid the "sensational" type of undesirable publicity, and will set the program on an even keel towards achieving prestige in the eyes of the profession, the community, the firm's own technical personnel, and in the eyes of present and future clients.



TOOLMAKERS POSITION FORMERS ON A FIXTURE USED TO MAKE INTERCHANGEABLE AIRCRAFT SUB-ASSEMBLIES.

The Assembly Problem

LELAND A. BRYANT
Consulting Engineer
Beverly Hills, Calif.

Inventor of the master tooling dock and many related devices, Leland A. Bryant is probably America's foremost authority on assembly tooling. He has served as a consultant to leading American firms and is also co-author of *Jigs and Fixtures for Mass Production.*

THE MOST REMARKABLE thing about the assembly problem is that it exists at all.

Airplanes, automobiles, railroad cars, seagoing vessels, and many other complicated products are designed today with unprecedented speed and precision. Tools are developed with which the component parts can be fabricated in any desired quality with reasonable economy. But when these parts are put together, our factories frequently function with all the efficiency of medieval craftsmen.

Shop workers must devote long and tedious hours to the task of trimming and selective fitting before the parts can be mated. And then assemblies must be produced with frequently inadequate tooling.

Why? Because often as not the fact that the product would have to be assembled was overlooked until after the design was frozen and the parts were in actual production. Even in our mass-production economy there are many people who believe that parts lacking interchangeable dimensions will be superior assemblies if mated by makeshift means.

There is ample evidence to prove that the as-

THE MASTER TOOLING DOCK IS USED TO CONSTRUCT ASSEMBLY TOOLS WITH SPEED AND PRECISION.

sembly problem can be solved. In the building trades, for example, architects are now so accustomed to preparing plans which will permit the use of efficient construction techniques that it is seldom necessary for men on the job to improvise work methods. This is done despite the fact that in many respects, construction work is probably the most limited production operation in modern industry.

Compromises between engineering and production ideals in the design of individual parts are commonly made in all industries. But when they are made without proper consideration of the assembly problem they often defeat their own purposes.

The assembly problem briefly involves:

1. The preparation of a parts breakdown which will make it possible to fabricate and assemble the components of a structure with available factory facilities in a quick and economical manner.

2. The provision of dimensional controls which will make it possible to assemble parts, sub-assemblies, and final assemblies without selective fitting.

In the aircraft industry, it is common practice to ignore these principles until prototypes have been constructed and satisfactorily flight-tested because it is obviously impractical to use the best types of production tooling methods in the construction of aircraft which might never be produced. Consequently, when they receive production contracts, aircraft manufacturers usually find that they must revise their prototype designs for production or continue using makeshift assembly tooling.

In practice, however, few prototype designs are revised to any great extent because of the resultant delays in starting production, plus the possibility of undesirable deviations in ultimate performance.

At Consolidated Vultee Aircraft Corporation shortly before the end of World War II, it was definitely proven that prototypes with good production designs can be made with temporary tooling for no more money than would be spent on prototypes with poor production designs; further, that time and money can be saved if adequate designs are available when production contracts are received.

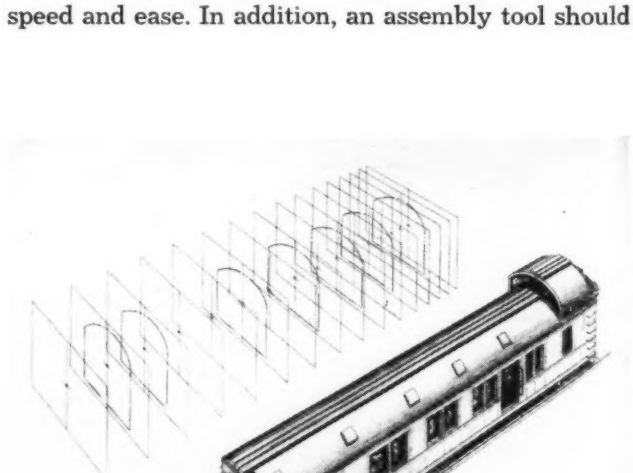
The nature of a parts breakdown for any given product should be determined by: 1) the relative cost of fabrication and assembly operations; 2) the required production quantity.

Where true mass-production requirements prevail, it is often desirable to break down a design to such an extent that many small and simple components can be rapidly fabricated and easily assembled over a large area by numerous workers with relatively little skill and training.

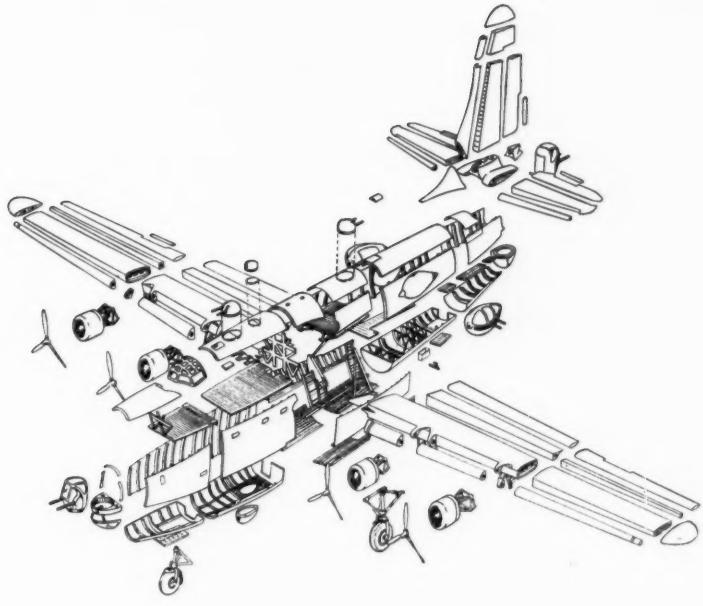
It is possible, in many cases, to fabricate one large part for less than the cost of fabricating and assembling two or more small parts. But large parts cannot be assembled as efficiently as small parts because their dimensions can prevent effective use of the best types of assembly jigs or fixtures. The sacrifice in basic production efficiency of large parts is compensated for in mass production by the considerable savings in handling of small components.

Assembly jigs or fixtures should include the following features:

a. Simplicity — The design of each tool should be such that it can be inexpensively fabricated and then loaded, worked, and unloaded with maximum speed and ease. In addition, an assembly tool should



A RAILROAD CAR AND THE GRID-PLANE SYSTEM THAT MIGHT BE USED IN DESIGNING THE CAR.



THE PURPOSE OF A PARTS BREAKDOWN OF A MODERN AIRFRAME, SHOWN HERE SCHEMATICALLY, IS TO PERMIT THE EFFICIENT FABRICATION AND ASSEMBLY OF THE COMPONENTS OF ANY OF THE GIVEN STRUCTURES.

be "fool-proofed" so as to eliminate the possibility of costly mistakes in mating parts.

b. Accessibility — An assembly jig or fixture should enable a worker to mate parts without excessive stooping, bending, or stretching, for even the best employee loses efficiency when fatigued.

c. Durability — No tool can be regarded as efficient if it will not withstand a reasonable amount of abuse without being constantly proofed.

d. Productivity — Each tool must constantly yield a pre-determined number of assemblies in a given amount of floor space if over-all production schedules are to be maintained.

e. Portability — An assembly tool should be portable, regardless of whether it is intended for use in the tool-fabrication area or in other areas. Any production unit may have to be moved for the sake of efficiency if practical experience proves that a preliminary floor plan is not completely effective.

f. Adaptability — The structure of the tool should be such that it can be modified, thus eliminating the need for a new assembly jig or fixture each time an engineering change becomes ncessary.

g. Salvageability — As many tooling components as possible should be standardized or designed so that they can be reclaimed for further use with minimum difficulty after an assembly jig or fixture has served its purpose.

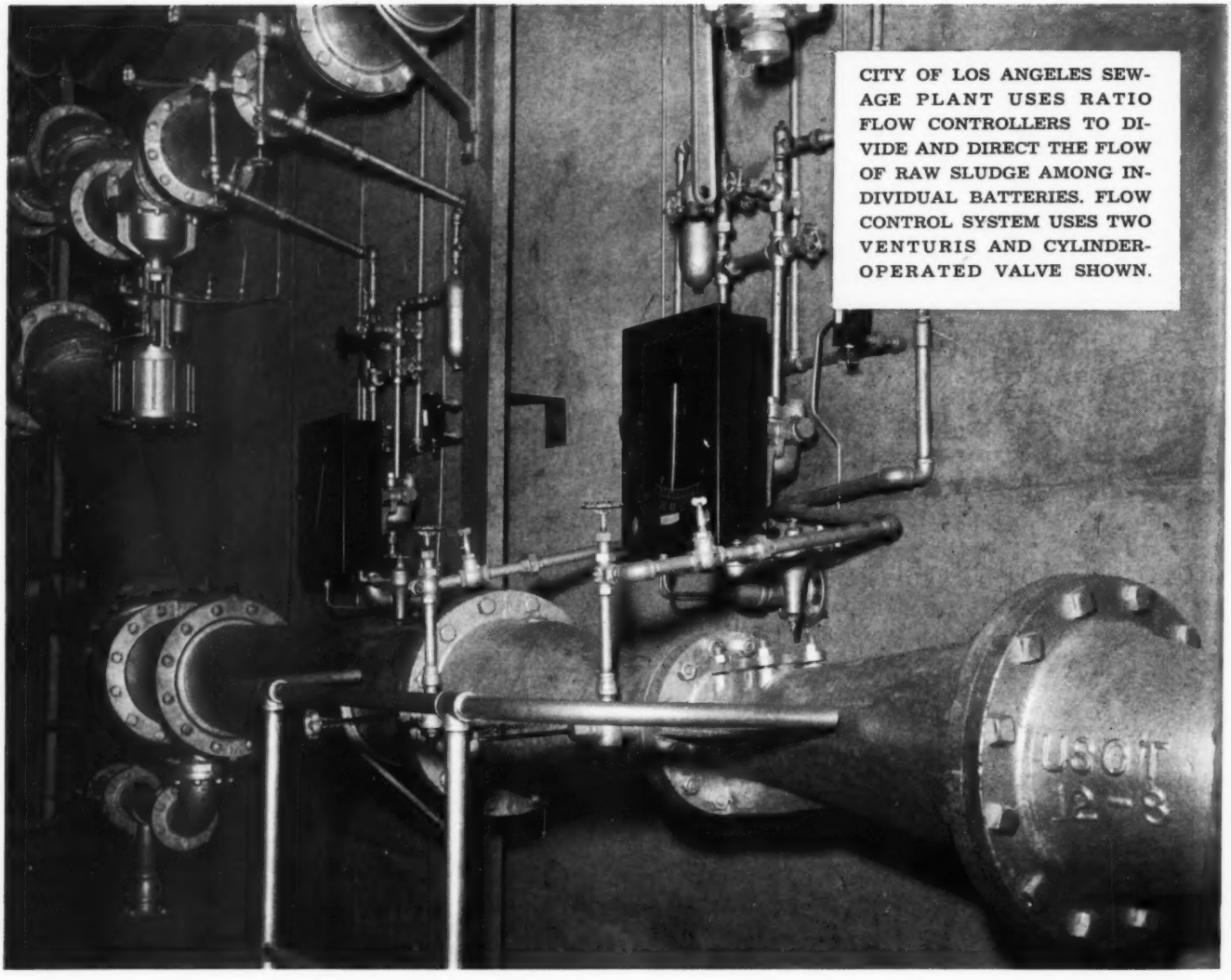
h. Safety — Any jig or fixture must be designed to minimize hazards endangering personnel safety.

The task of providing dimensional controls which will permit the production of interchangeable parts, sub-assemblies, and assemblies is primarily a matter of developing or utilizing a common source of measurements for the fabrication of all tooling—including molds and dies as well as jigs and fixtures—for the manufacture of a given product.

Where measurements for critical dimensions are taken from more than one source, deviations are bound to occur because no two measuring devices are quite the same. Individually, such deviations may be slight and even insignificant. However, since they are also cumulative, they can lead to substantial errors, especially where several sources of dimensional information are used in the fabrication of a large number of tools.

Preferably, the source of dimensional information should be a device such as a master gage or mockup which is non-susceptible to human errors (since they, too, can be cumulative). In utilizing the common source of data, it is necessary to distinguish critical and non-critical dimensions. Too much precision can be as costly as too little. An automobile body, for example, may serve its purpose quite well despite the fact that it is slightly longer or slightly shorter if only a few of its components have been situated with such accuracy that they can readily be assembled with the chassis. This is an especially important point to bear in mind where large numbers of parts and assemblies must be procured from sub-contractors, for complete dimensional coordination could not be attained at a reasonable cost.

Where the principles of efficient production are recognized, the main question that must be answered is, "how can we give engineering, tooling, and production problems the consideration each deserves in the development of a new product?" Teamwork is the only possible answer. Engineering, tooling, and production personnel must all have an opportunity to contribute to development of the product.



CITY OF LOS ANGELES SEWAGE PLANT USES RATIO FLOW CONTROLLERS TO DIVIDE AND DIRECT THE FLOW OF RAW SLUDGE AMONG INDIVIDUAL BATTERIES. FLOW CONTROL SYSTEM USES TWO VENTURIS AND CYLINDER-OPERATED VALVE SHOWN.

Techniques of Flow Control

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Industrial Division
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CONTROLLING the flow rate of such fluids as water, steam, gases, and processing liquids ranks as one of the most important jobs for instrumentation. The majority of flow control systems employ the orifice-type meter in which the rate of flow is obtained by measuring the differential pressure created across a small orifice or similar constriction in the pipeline.

Area flowmeters (also known as rotameters), however, have been developed in recent years for practical industrial use, and they are particularly suitable for applications where low rates of flow are encountered. This type operates on the principle that a float, supported by the flowing fluid in a vertical tapered tube, rides in a position (exposes an annular area) which is in direct proportion to the rate of flow. The force exerted by the fluid flow pushes the float up, indicating the flow rate.

Orifice Meters

Two types of orifice meters are commonly used for flow control. The mercury manometer is available in many styles for locally mounted controllers

as well as with electric or pneumatic transmission systems for remotely mounted controllers. Also available are the newer mercuryless manometers such as the pneumatic-balance unit. This is a non-indicating pneumatic transmitter widely used in conjunction with a separate stack-type controller and a miniature recorder or indicator. See Fig. 1.

Basic Orifice System

As illustrated in Fig. 2, the basic system for control of flow in a pipe with an orifice meter includes an orifice plate (or flow nozzle or Venturi tube) in the pipeline. High and low pressure connections are made to the flow controller, which in turn operates a control valve downstream from the orifice.

Changes in flow are picked up as changes in differential pressure across the orifice; the controller repositions the control valve to maintain the rate of flow at the desired value. In some cases, the control valve is better located upstream from the orifice; a general rule is that the controller should be placed so that the most constant pressure (either upstream or downstream) is one of the orifice pressures.

Pneumatic-operated controllers are employed in the majority of flow control systems today because the required throttling action is more easily obtained in this type of control. Recent innovations have made electric proportional control systems more practical for flow applications, but usually an electric-pneumatic relay is used on a pneumatic-operated control valve. A valve positioner on the valve is generally recommended for best results in all flow control applications

Liquid Control

Where liquids flowing in a pipe are under a constant pressure maintained by means of a second control, or when they are under pressure supplied by hydrostatic head, the simple arrangement shown in Fig. 1 works quite satisfactorily. This applies where it is desired to control the discharge of a centrifugal pump which is run at constant speed; control is provided by a throttling valve in the discharge line. A bypass valve is sometimes used to carry a portion of the discharge continuously but, for best control, the entire flow should pass through the control valve. The bypass should be used only in case of emergency repairs on the control system.

With positive-displacement pumps, placing the control valve in the discharge line as a means of control can result in the build-up of destructively high pressure, should the valve be fully closed. In such an installation, a pressure-limit controller should be installed in the line, set to shut off the steam or other power source if excessive pressure is developed. Because of this complication, control of the discharge from positive-displacement pumps is often accomplished by one of two other means: by regulation of pump speed, such as by throttling of steam supply to the pump, or by location of the control valve in a bypass line which returns a portion of the pump discharge to the suction side of the pump. See Fig. 3.

Power Unit

If the pump is a steam-turbine-driven type, the system shown in Fig. 3 (left) may be used, or a pneumatic power unit may be fitted to the turbine throttle valve. The hydraulic governor is placed between the power unit and the throttle valve. The governor adds stability to the positioning of the turbine throttle valve, which usually has a very small travel.

If a pump is equipped with standby electric power as well as with a turbine drive, the flow controller

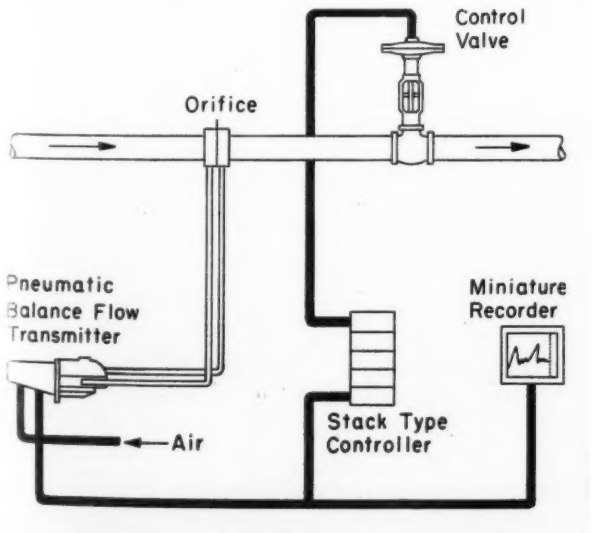


FIG. 1—MERCURYLESS MANOMETER IS EMBODIED IN PNEUMATIC-BALANCE TRANSMITTER USED HERE.

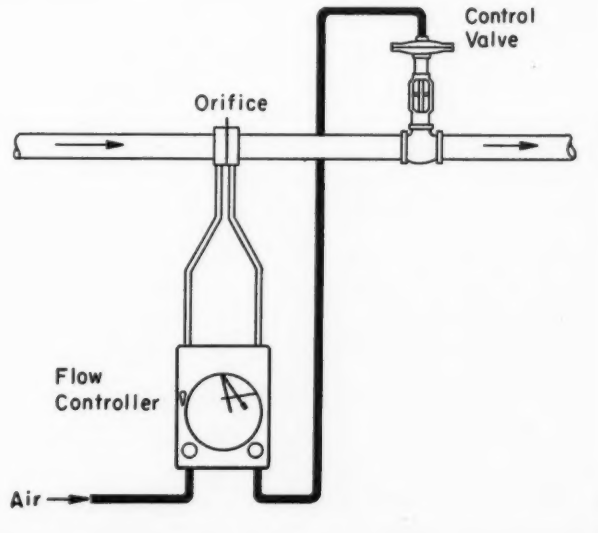


FIG. 2—SIMPLE FLOW CONTROL SYSTEM USES ORIFICE METER DATA TO OPERATE A CONTROL VALVE.

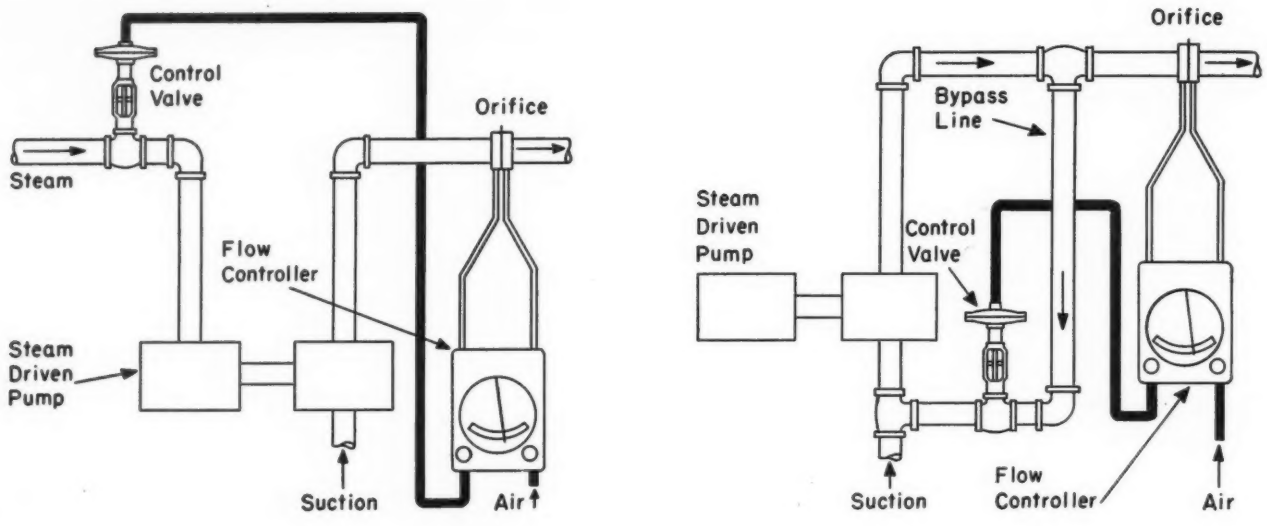


FIG. 3—PUMP DISCHARGE IS CONTROLLED BY REGULATING STEAM SUPPLY (LEFT) OR BY BYPASS VALVE. (RIGHT).

can be arranged to control either the turbine throttle or to control a bypass valve which is used with the electric-motor drive. Flow control can also be employed for large crank-and-flywheel types of steam engines which use low-pressure steam; the control valve is placed in the steam line feeding the engine as previously described for positive-displacement pumps. A gas-engine drive can also be regulated by means of a diaphragm motor working the set point of the governor.

In general, where pump speed is controlled, the flow control system does not react as instantaneously as when flow is controlled by valves. When the inertia of the pump is small, there is little affect. But on larger installations, the flywheel effect of the pump causes a lag which will produce cycling if not controlled by a carefully adjusted proportional-reset controller.

Variations in steam pressure will affect the controlled flow, acting just as changes in control valve position would act; thus, the steam pressure should be controlled automatically if it is expected to vary appreciably and if consequent changes in flow are significant. Control of pump speed where larger flows are involved has an important economic advantage in that it avoids the expense of large control valves required in systems with the valve in the discharge line.

Gas or Steam Flow

The control of gas or steam flow is similar to that of liquid flow, except for the factors introduced by the compressibility of gases. Location of the control valve with respect to the orifice depends upon whether the flow is to be controlled on the basis of downstream or upstream gas pressure. If the downstream pressure of the gas is constant at a constant flow, the valve is placed upstream as shown in Fig. 4. The "straightening vanes" may be required to smooth out the flow if a sufficient run of pipe is not available between the valve and measuring orifice. In cases where the gas pressure upstream is constant and the downstream pressure is variable, the valve is located downstream as illustrated previously for the basic control system (Fig. 1).

In certain applications, control is desired on the basis of absolute volume regardless of variations in line pressure. Meters are available with compensation for static head, a pressure connection simply being tapped into one of the orfice connecting lines;

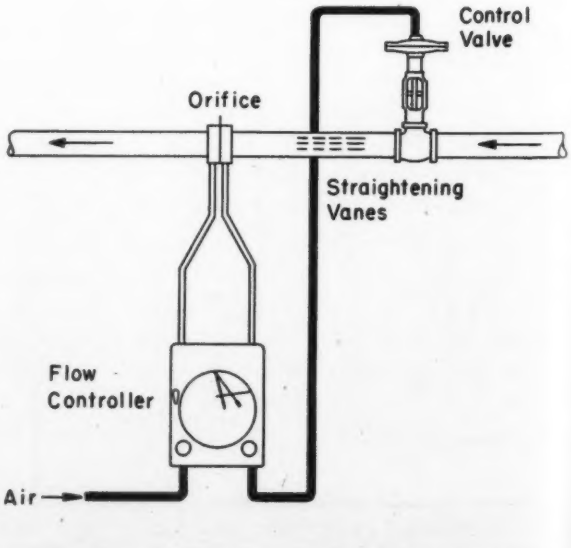


FIG. 4—CONTROL OF GAS FLOW IS MAINTAINED WITH THE DOWNSTREAM FLOW RATE KEPT CONSTANT.

with the measurement thus corrected, flow control is placed on the basis of absolute volume.

In blending or chemical treating operations and similar problems, it is often desirable to maintain the rates of one or more flows in a fixed ratio to another flow which may vary as determined by the process. For example, the process may require addition of fluid "A" in a ratio of 2:1 to fluid "B"; if "A" is uncontrolled and flowing at a rate of 100 gpm, then "B" should be regulated to be 50 gpm. Similarly, if "A" increases to 200 gpm, "B" should immediately be corrected to flow at 100 gpm. In this system, the uncontrolled flow of "A" is termed the primary flow and the controlled flow of "B" is termed the secondary flow.

As shown in Fig. 5, pneumatic transmission of flow data is combined with a ratio flow controller in a single system for ratio flow control. Changes in the uncontrolled primary flow "A" are caused to continuously reposition the set point of the controller for the secondary flow "B". Flow "B" is maintained at a fixed ratio to flow "A". The required ratioing is provided in the controller by a bellows mechanism which is essentially a pneumatic receiver for the primary flow with an adjustable linkage to the controller set point. Aside from the continuously adjusted set point, the controller functions in the normal manner, positioning a control valve on the secondary flow line.

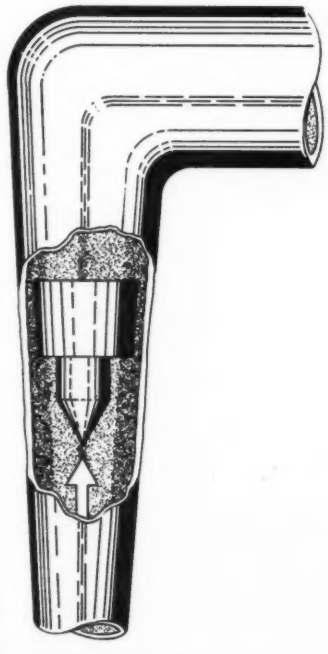
The ratio mechanism has an adjustment which permits variation in the controlled flow ratio from 50 to about 150 per cent; i.e., a ratio of primary to secondary flow from 1:2 to 1½:1. It is important to note that the basic ratio of the two flows to be proportioned can be almost any desired value. The size and fluid pressure of the process lines, as well as the orifice design for the flow meters actually determine absolute flow rates. The established ratio is then maintained by the ratio control system, or can be set at some other value within the range of the ratio adjustment.

Establishing Ratios

For example, if the basic ratio of secondary to primary flow is to be 6:1, the piping system and orifices are designed to provide approximately this ratio (excluding the effects of the ratio controller). The ratio controller set at 100 percent will maintain this relative proportion of flows. The 6:1 flow ratio, however, could be decreased to 3:1 by reduction of the ratio setting to 50 percent, or it could be increased to 9:1 by a ratio setting of 150 percent.

Adaptations of the basic system may be made to handle a variety of control problems. In a blending operation for example, instead of two additive flows being ratioed to each other, one additive flow and the total flow can be metered and the other additive flow controlled accordingly to control the ratio of the two flows. This might be done to avoid a difficult metering problem with one of the additive flows involved (too high a viscosity, for example).

Another adaptation of the basic system is the ratioing of several flows in relation to one uncontrolled primary flow. This merely involves the connection of several ratio flow controllers in parallel with the primary flow transmitter and separate flow transmitters for each of the secondary flows. Such a system has been applied to the continuous treatment of large quantities of river water used in a plant. The water was considered the uncontrolled primary flow to which the various treating agent-flows were proportioned by ratio controllers.



AREA FLOWMETER USES FLOAT POSITION TO MEASURE FLOW.

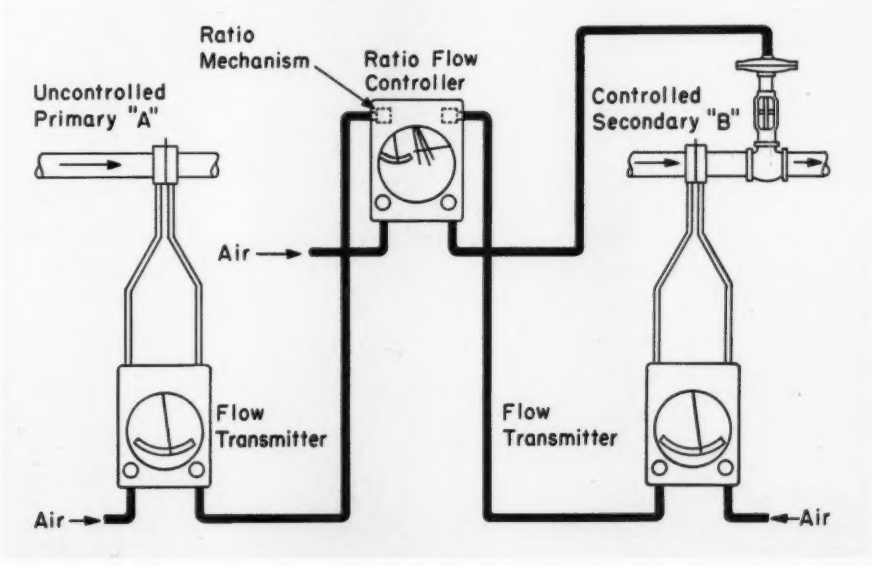
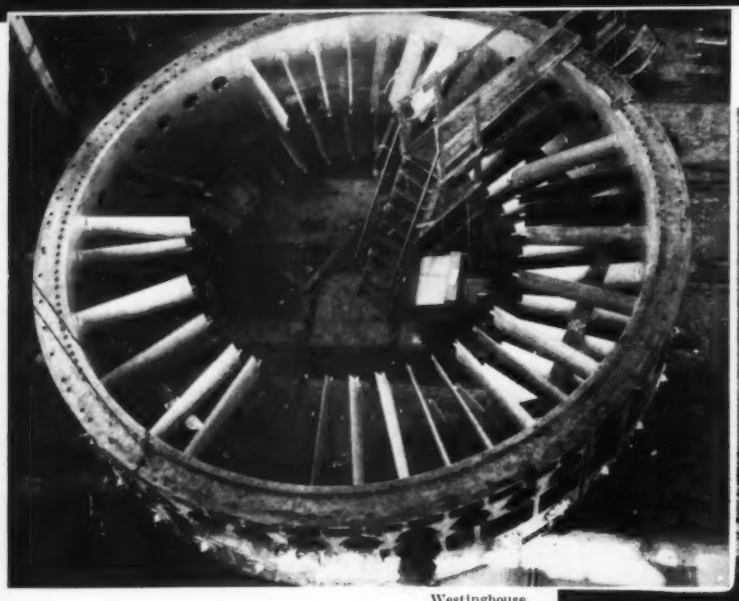
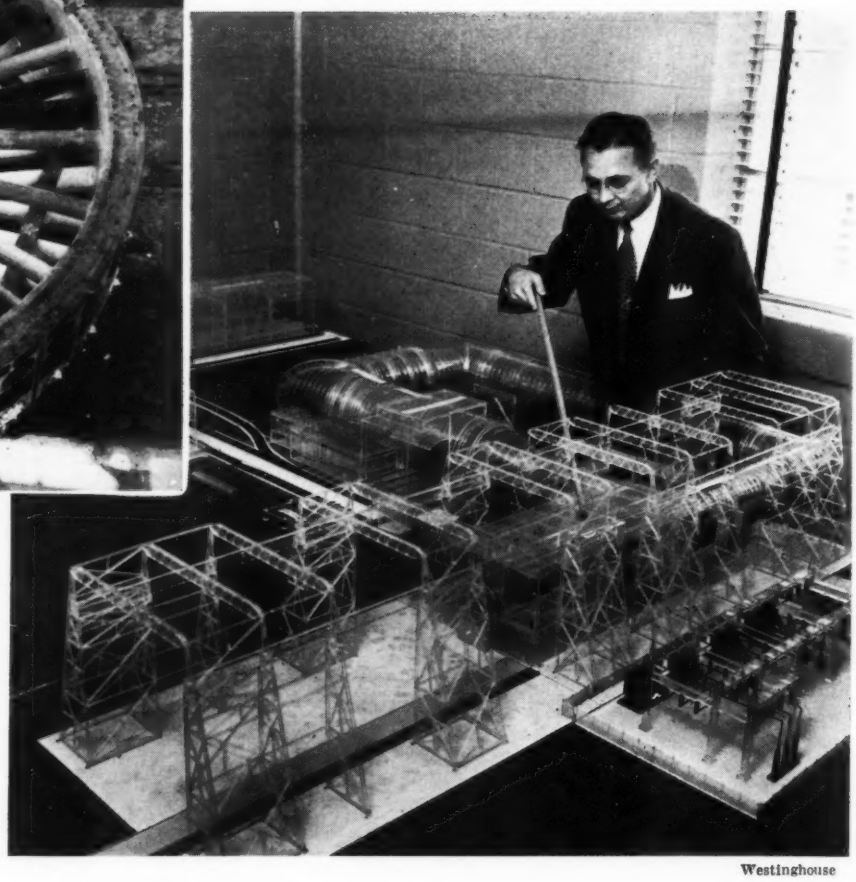


FIG. 5—THIS RATIO FLOW CONTROL SYSTEM USES TWO PNEUMATIC TRANSMITTERS AND RATIO CONTROLLER TO CORRELATE FLOW "B" WITH FLOW "A".



Westinghouse



Westinghouse

WORKERS STANDING BEHIND THE STAIRWAY IN THE CENTER OF THIS COMPRESSOR STATOR FOR AN AIR FORCE WIND TUNNEL ARE DWARFED BY THE SIZE OF THE STRUCTURE (ABOVE); ENGINEER (RIGHT) POINTS OUT IN THE PLASTIC MODEL THE BUILDING WHICH WILL CONTAIN THE DRIVING MOTORS AND COMPRESSORS.

Plant Layout in 3-Dimensions

A STAFF REPORT

South Bend Lathe

THE BEGINNINGS OF A SMALL MACHINE SHOP TAKE THIS PRELIMINARY FORM USING SCALED-DOWN TOOLS.

THREE-DIMENSIONAL models are helping plant designers who might otherwise find themselves with a problem akin to the too-ambitious basement boat builder — he can be sure that his plant will be big enough to house all that must go into it. And experience is proving that far more money is saved all along the line than the models cost.

All across industry, three-dimensional miniatures are being employed in wider applications than just design. Work scheduling, incentive programs, training programs, safety planning, — all these are activities in which a scaled model of the plant is invaluable. A rather typical situation developed when the construction people on a job decided they needed the model before the designers could finish all their detail work. It was a running battle, the construction people demanding use of the building model all during the time the designers were trying to wind up their work.

Model for Construction

The interest of the construction men was natural. They could see the plant as it was to be and then could decide what should go in first, where clearances should be maintained until later work would

be completed, and what materials should be ordered to the job site first (important if the site is crowded) so that no pileups occur before the material can be put in place.

Where does all this interest stem from? Probably from the simple fact that scaled models are the nearest thing to reality available. They have their greatest value in planning installations where best usage of cubical contents is required. This means that chemical plants, which are generally tall compared to floor area, are ideally suited to being modeled. Until recently, many felt that the specialized nature of chemical process equipment made accurate models too costly. But even admitting that custom-made models are the most expensive, it still is worth the cost to build the model.

Cost Estimates

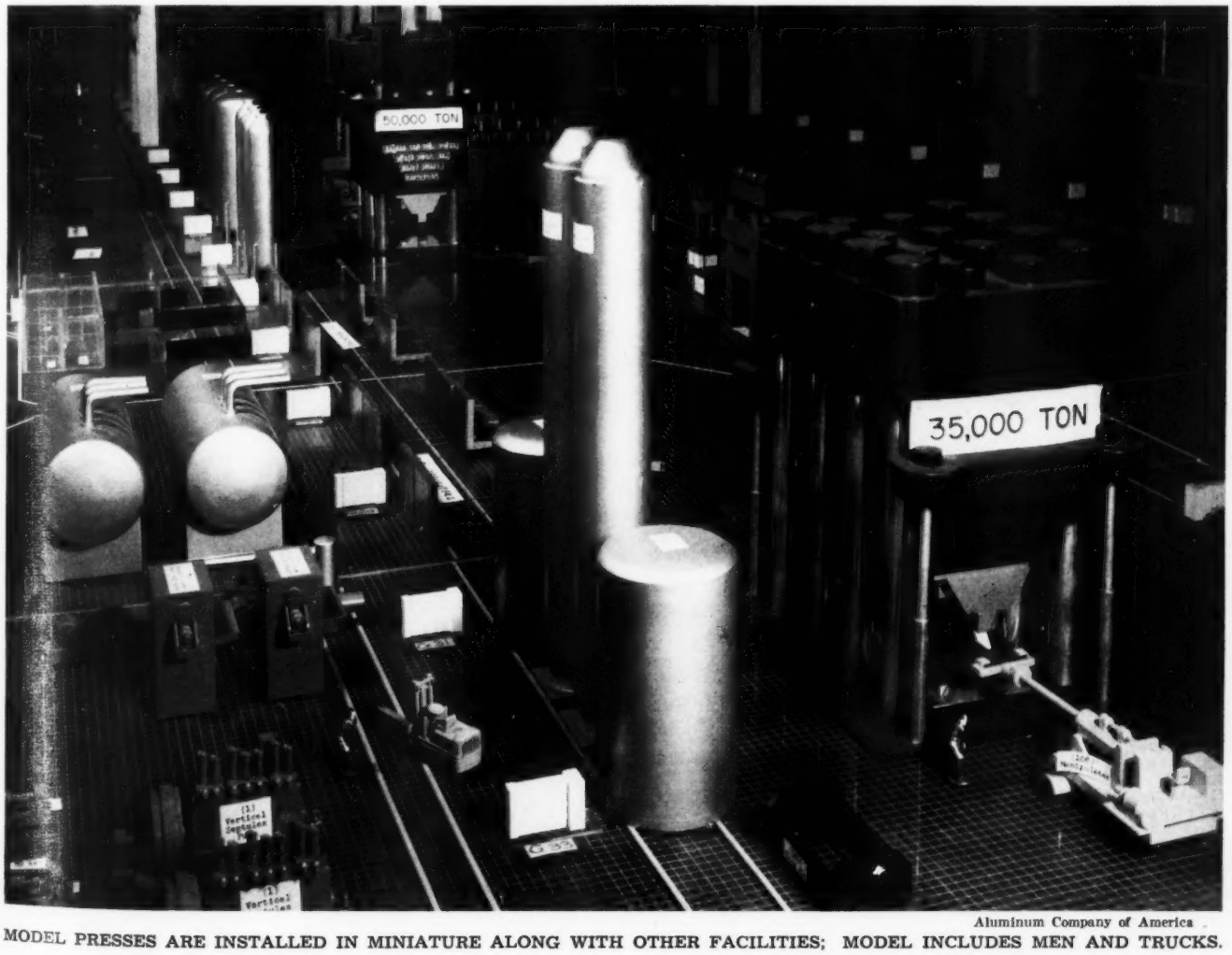
Guesses as to the cost of a complete three-dimensional scaled model range from 0.1 to 0.4 percent of the total plant cost. This figure depends somewhat on the scale chosen and on the availability of stock models which may be applicable.

But the gains are impressive when added up. First, there is the obvious advantage that any errors in placement or routing can be spotted in the model immediately. This means error correction at minimum cost. Certainly it is cheaper to move a miniature mockup than to call in the millwrights, pipefitters, electricians, and their crews to move the real thing.

Design Savings

In design itself, there are savings which can be seen immediately in such things as piping layouts. A three-dimensional miniature helps the designer think more in vertical terms — layout becomes a matter of using up building volume rather than just using floor area. For example, directional lanes can be established in horizontal and vertical layers which will shorten piping runs and which will put control valves within easy reach of the worker (who is not yet on the scene to complain about the valve he can barely reach). And especially in those chemical plants using stainless steel pipe, every foot saved on a run is a substantial saving.

There are other factors which are not of primary design importance but which are none-the-less significant. Many executives and departmental supervisors (and engineers) must be consulted for ap-



Aluminum Company of America

MODEL PRESSES ARE INSTALLED IN MINIATURE ALONG WITH OTHER FACILITIES; MODEL INCLUDES MEN AND TRUCKS.

Visual Production Planning

MACHINE SHOP IS LAID OUT ON A SCALED FLOOR SO THAT CLEARANCES AND SPACINGS ARE IMMEDIATELY DETERMINED.

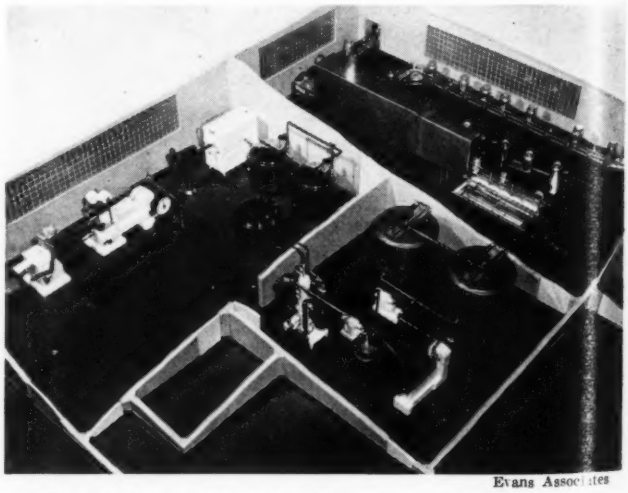
but most are simply not able to make sense out of blueprints. Yet there are the many sets of drawings which they must consider — foundation diagrams, structural layouts, equipment arrangements, piping layouts, electrical drawings, heating and ventilation diagrams, fire protection layouts and more. It is far simpler to show such men a three-dimentional model than to try and force them to see three dimensions by showing them dozens of two-dimensional drawings. Models make possible the widest dissemination of the scope and progress of plant design.

Beating Deadlines

Scaled plant models make it possible to get plants into full scale operation faster. This is important in very basic financial terms. It can mean beating completion deadlines and avoiding penalties. It may also mean that a plant can begin earning its keep for its owners sooner; money invested in the plant will not remain idle as long. If plant operations can begin early — even a few days — the additional earnings will often completely pay off the cost of the model and all the other advantages of having the model will come free.

There are two primary ways in which the model hastens plant completion. The first stems from its function of pointing out errors in advance of construction. Correcting design errors on the job costs time as well as money. In addition to the higher costs of correction during actual construction, there is the lost time which may cost even more in terms of penalties and lost production.

The other factor develops from the ability to train supervisory and operating personnel before the plant is completed — by using the model. This con-



Evans Associates

THIS DAIRY PLANT WAS CONSTRUCTED IN MINIATURE, COMPLETE WITH THE WALL SECTIONS AND PIPING.

siderably reduces the shakedown time after full-scale plant operations actually get underway. Many organizations keep their plant models permanently as training aids.

Later Uses

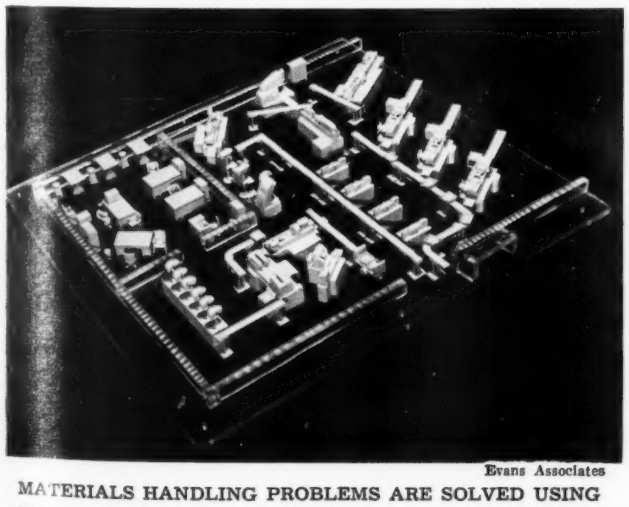
They keep their models for other reasons, too. Changes in plant function, introduction of new processes and new equipment, adoption of new methods — any one of several such factors can come up during the lifetime of a plant and cause what is essentially re-layout of the plant. And all of the advantages which the model first presented are parlayed when the problem of layout comes up again. If the model exists, it is the first place the engineers go to see what the plant is actually like and what changes can be made.

Building Up the Model

As there are no two plants that are alike, so there are probably no two models that were put together alike. Where there is continuing need for model work, some firms maintain libraries of stock equipment miniatures and order special items only when needed. Some make their own models as needed or have a man or two in the shop who meet the need when stock models don't fill the bill. One supplier lists over 10,000 machine and components models; the need for special models would seem to be rather rare.

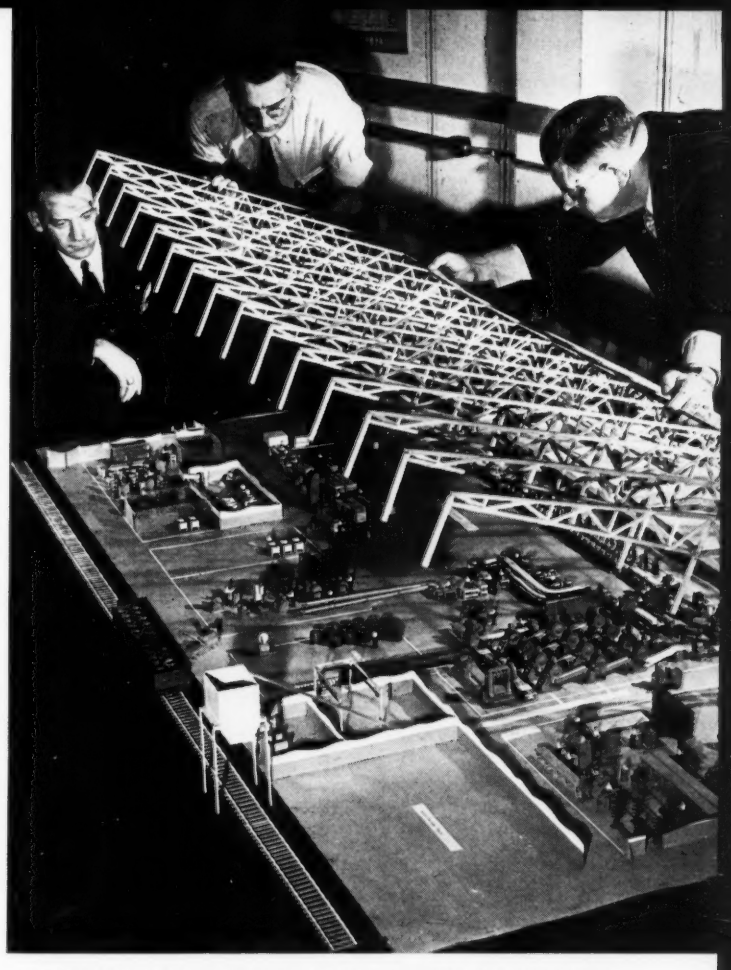
Assembling the plant in miniature may follow several paths. Some groups are advanced in the art to the point where they make three classes of models, each class following the other as design progresses. Others just build their miniatures up from start to finish gradually.

Walls may be made from plastic sheet. Soft wood can be easily modeled into special shapes. Dowels make pipe; wires make cable; tubing makes columns and vessels; fly screen makes grating. More sophisticated tastes take it from there. (Some groups have had trouble with artistic temperaments which insist on carrying detail to aesthetic limits; the objectives of the modeling project must be defined, else it be carried away.)



Evans Associates

MATERIALS HANDLING PROBLEMS ARE SOLVED USING PLANT MODEL COMPLETE WITH THE CONVEYORS.



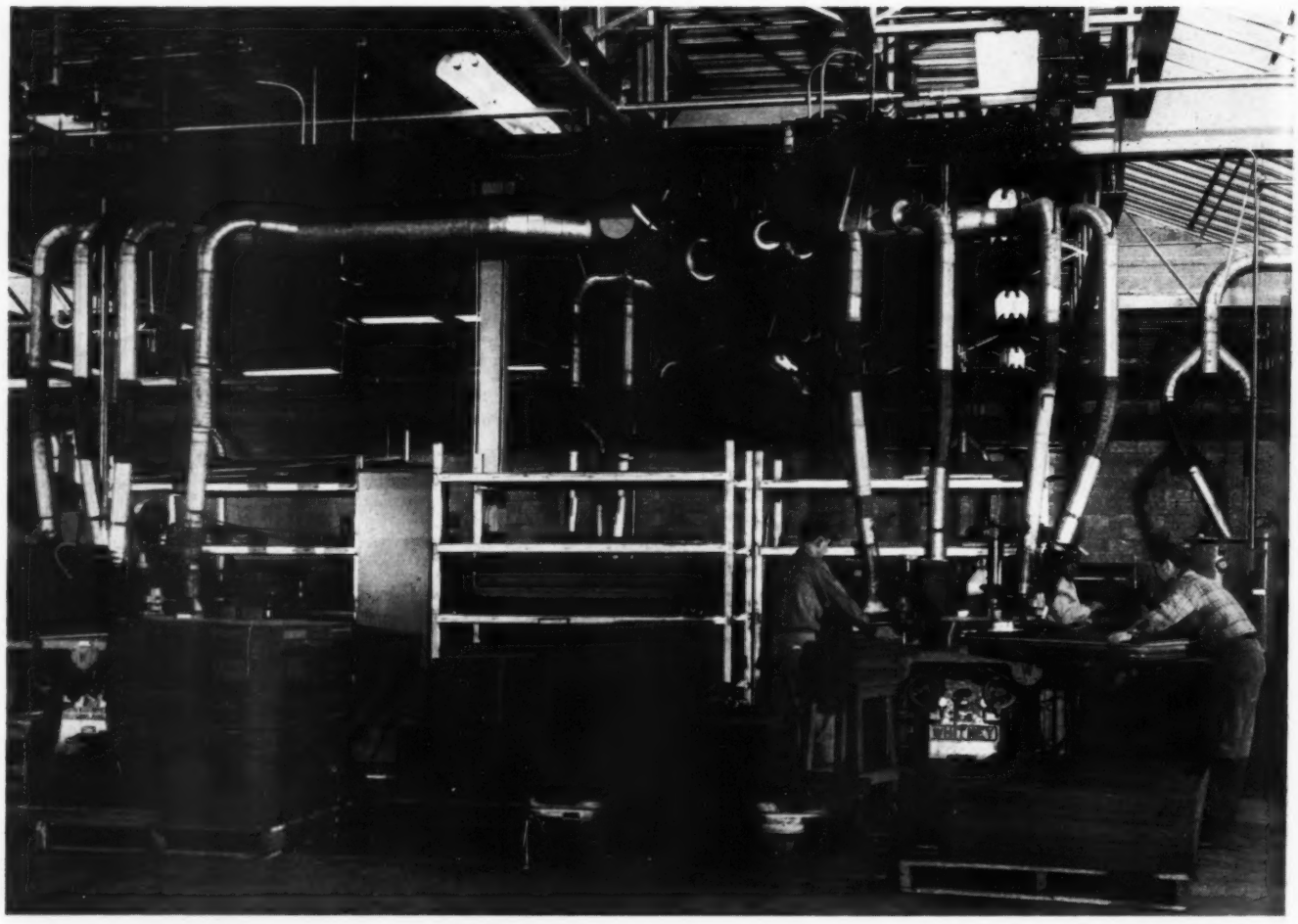
PLACING ROOF STRUCTURE ON FINISHED MODEL WILL PERMIT IMMEDIATE STUDY OF OVERHEAD CLEARANCES.

Limitations

The models do have some limitations. Some are known to have been shipped safely over long distances in panel trucks, but this cannot dispute the fact that drawings can be distributed far more cheaply than any model. When only one model exists, its use cannot be extended by making dozens of duplicate copies as is the case with drawings. Photographs help some, but they merely present a two-dimensional perspective which is partial substitute for the model itself.

Few who vigorously advocate the miniatures would say though that drawings are outmoded. Dimensions for actual construction cannot be taken from the model, the dimensions simply cannot be shown on the model. Perhaps if the attempt were made, the resulting clutter would detract from the model's effectiveness.

But the plant miniature has proved itself in terms of dollars saved, time gained, and frustration avoided. It has made the subject matter of blueprints understandable to many of those who are concerned and who now can comprehend all significant details of design before the plant goes up.



EXHAUST HOODS AT WOODALL INDUSTRIES, INC., MINEOLA, N. Y., COLLECT MASONITE DUST FROM SHAPER OPERATIONS. FLEXIBLE CONNECTIONS ON BRANCH PIPES PERMIT LIMITED MOVEMENT FOR USE AS VACUUM CLEANERS.

Selecting Equipment For Industrial Dust Control

W. O. VEDDER, Manager
Dust Control Department
Pangborn Corporation

PROPERLY PLANNED and installed dust control systems are becoming an increasingly vital part of many modern industrial plants. Although such systems are often necessary to comply with local air pollution laws which prohibit exhausting dusts into the atmosphere, a number of equally important benefits are derived.

Control of dust within the plant improves working conditions, thus contributing to higher production and lower employee turnover. In many instances, dust collection also provides a means of reclaiming useable materials. In addition, proper dust control permits recirculation of cleaned air, prevents exhausted dust from re-entering work areas, improves plant housekeeping, decreases building maintenance, and cuts wear and maintenance on operating equipment.

Components of a dust control system include the exhaust hoods and piping system, dust collecting equipment, and the exhauster and its drive. Each must be considered separately in relation to the type and amount of dust to be handled.

Exhaust hoods to a large extent govern the effectiveness of dust control. Therefore, dust producing operations and processes should be as completely

enclosed as possible. Next to complete metal enclosure, canvas or rubber drop curtains are recommended. When complete or semi-enclosure of the process is impossible, the exhaust hood should be located as close to the point of dust production as possible. Hood design varies to fit the type of process covered. Hoods, along with flanges, baffles, skirts, and vanes, should direct maximum flow from the dust producing area with minimum flow from surrounding areas where no dust is generated.

Velocity contour curves should be consulted for different hood shapes when the hood is being designed. These curves indicate velocities and flow lines at various distances from the hood and are helpful in selecting hood shape and size. These curves are found in a number of reference books.[1]

Manufacturers of equipment which tends to produce dust while in operation are now designing enclosures and hoods as an integral part of their original equipment. This usually provides a more effective hood design than can be developed in the field by the purchaser.

PERFORATED PLATES COLLECT DUSTS FROM WORK TABLES IN THOMAS A. EDISON BATTERY PLANT.

Piping

Diameter of piping used to connect exhaust hoods to dust collecting equipment depends upon the volume of air to be removed and the velocity at which it should be withdrawn. Many local codes specify connection sizes and air volumes for various operations. In other instances, pipe sizes are determined by calculation and by experience. When calculating for the cross-sectional area of any pipe, the air volume to be removed is divided by the velocity recommended to remove the type of dust in question. Capacities of branch lines are totaled to give the volume in main lines.

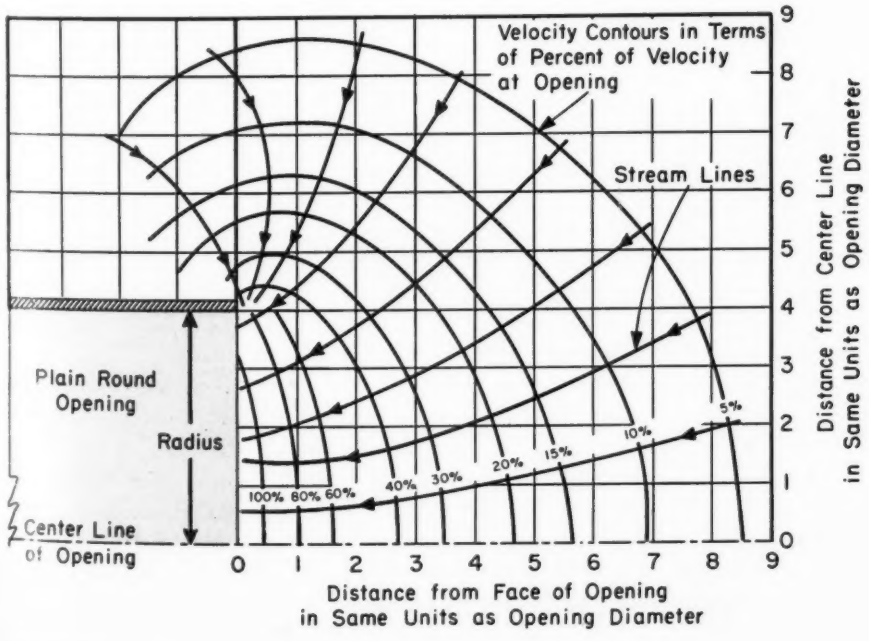
Eight general suggested specifications for average duty, industrial exhaust system piping are:

1. Keep bottom of pipe straight to avoid dirt-collecting pockets. Make changes in area with gradual taper, top and sides only.

2. Make branch connections only into side or top of tapered section of main-pipe. Angle should not exceed 45 degrees, and should preferably be 30 degrees. Branch connections should enter near the large end of a tapered section.

3. Lap joints should be in the direction of air flow. Keep piping free of obstructions.

4. Piping should be substantially supported



VELOCITY CONTOURS AND DIRECTION OF AIR FLOW FOR CIRCULAR PLAIN OPENINGS WITHOUT OBSTRUCTIONS. CURVES OF THIS TYPE PERMIT GRAPHICAL DETERMINATION OF AIR VELOCITIES AT ANY POINT IN FRONT OF AN EXHAUST HOOD AS CHARTED.

by strap iron, angle hangers, or rod hangers.

5. Provide cleanout openings in lower side of pipe at regular intervals and adjacent to bends, junctions, and vertical risers. Provide end cleanouts with removable caps.

6. Elbows and bends should be formed with smooth curves having a center line radius equal to twice the pipe diameter, and should be constructed two gauges heavier than straight sections.

7. Blast gates for system resistance adjustment should be located in branches close to their junction with the main pipe, and should be provided with a means for locking in adjustment.

8. Construct piping of galvanized steel with riveted and soldered or lock seam joints; or black steel with welded joints of the following gages:

4 to 12 in. dia—No. 20 ga.
12 to 32 in. dia — No. 18 ga.
32 in. dia and over — No. 16 ga.

Dust Collectors

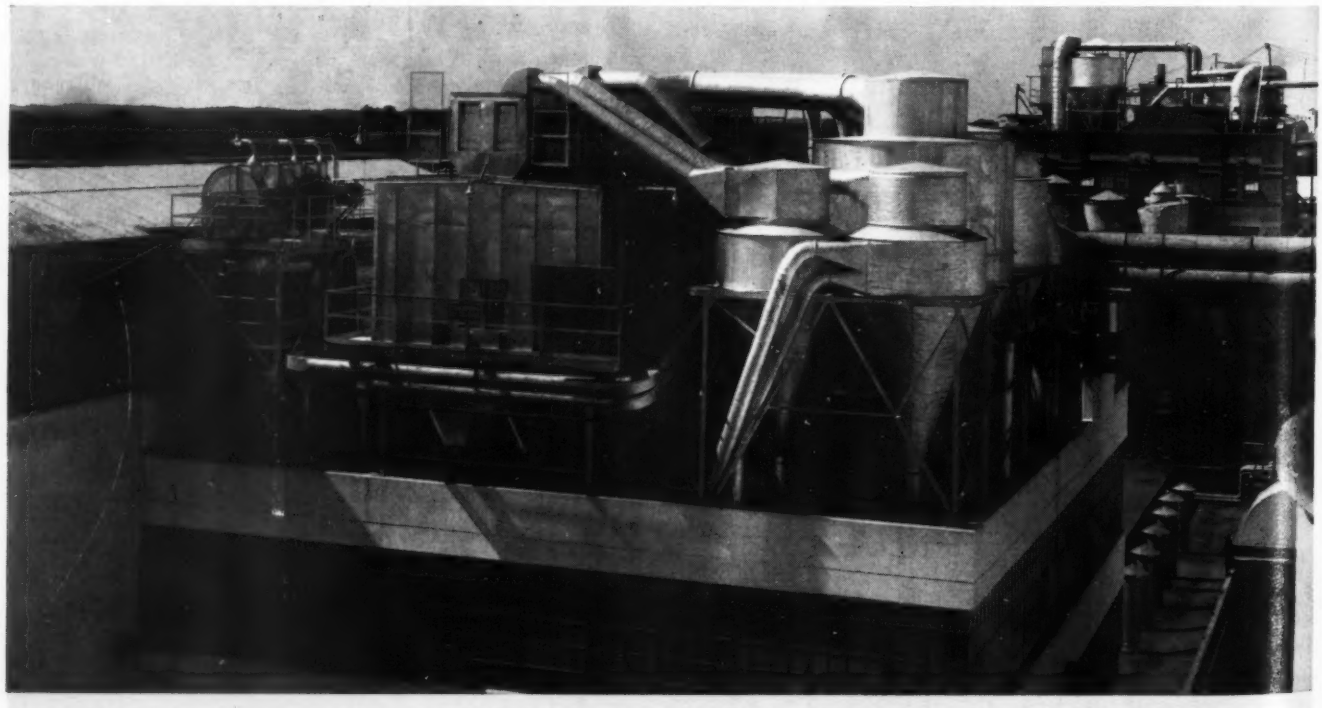
There are many types of collectors in general use in the dust control field. Although each major type has been designed for specific applications, these fields overlap to a degree and no hard and fast rules for selection can be established.

Settling Chamber — The simplest and most economical means of removing dust from the conveying air is accomplished through a reduction in air stream velocity. This method is effective only in removing relatively coarse particles and its application is limited. Some improvement in settling efficiency can often be accomplished by installing baffle and deflector plates. Primary use of the settling chamber is as a presettling means to reduce the dust loading ahead of more effective dust collecting equipment.

Centrifugal Type Collector — Centrifugal type collectors utilize radial acceleration of an air or gas stream to separate solid particles. The common large diameter cyclone is widely used, but it is effective principally on coarser particles, an outstanding example being the wood working plant's shavings exhaust system. More recent designs include the small diameter, high speed and the multiple type cyclone collectors which accomplish a higher degree of separation through higher centrifugal forces, but with resultant increase in resistance.

Baffle Type Collector — Essentially, the baffle type collector is a settling chamber fitted with baffles, vanes, or deflectors which accomplishes dust settling through velocity reduction and centrifugal action. It is particularly suitable to the removal of coarser particles in higher temperature installations since the design lends itself to all-metal construction. Frequently it is provided with an auxiliary water spray compartment to improve over-all efficiency.

Dynamic Type Centrifugal Collector — This device is essentially a combined fan and centrifugal collector, serving as a source of air movement as well as a means of removing dust through the centrifugal forces developed by the impeller. It is principally applicable to removal of coarser particles,



CENTRIFUGAL AND CLOTH SCREEN COLLECTORS INSTALLED AT THE BATTLE CREEK, MICH. PLANT OF KELLOGG CO. RECOVER AN AVERAGE OF 35 TONS PER HOUR OF GRAIN DUSTS. RECOVERED MATERIAL IS WORTH $40 PER TON.

and is similar in collecting efficiency to a well designed centrifugal collector.

Wet Type Collector — In wet type collectors, the dust particles are entrapped in a liquid, usually water, and conveyed by the liquid to a settling tank or disposal area. The basic types of wet collectors are the water curtain, dynamic precipitator, and impingement types, and combinations of these types. Wet type units are well adapted to higher temperature problems and to applications involving high moisture content.

Electrical Precipitator — In this method, an electrical field between electrodes in the air or gas stream is used to remove suspended particles. In the usual form of precipitator the negative electrode is of a comparatively small diameter, and it is placed close to the larger positive electrode. The negatively charged dust particles are attracted to the positively charged electrode and collect on its surface. From here the precipitated material either drops by gravity into hoppers, or is dislodged by interrupting the current and rapping the plate periodically.

Electrical precipitation has been used extensively for many years in conjunction with the flue gases in smelters, sulfuric acid plants, cement mills, and in plants for cleaning and detarring gases. In large central power stations using pulverized fuels, the process is used to remove fly ash and other solid impurities of finely divided nature. The over-all recovery efficiency of properly designed and applied electrical precipitation equipment is high on all particle sizes. However, due to its high initial and maintenance costs, its use has been chiefly confined to higher temperature problems.

Cloth Type Filter — This type of collector filters dust from the conveying air by flowing the air through specially designed filter fabric. Many variations in design are available. The cloth type filter is in general use for problems involving the collection of finely divided dry dusts and accomplishes high recovery at economical cost. In general, it consists of a tight casing enclosing the filter fabric in such a manner that all incoming air must pass through the fabric to the collector outlet. Upon entering the collector, a reduction in velocity causes the coarser particles of material to drop from the air stream. The remaining dust is then filtered from the air stream by the cloth and the cleaned air continues on to the collector outlet. The dust pack or mat thus formed on the cloth surfaces materially assists in improving the over-all recovery efficiency.

Two major types of cloth filters are available — the tube or bag type, and the cloth-screen type.

In the tube or bag type, the filter fabric takes the form of a series of tubes or bags which are open at one end and closed at the other. They are suspended vertically in the casing with the bottom end tightly sealed to thimbles in a plate. The dust laden air enters the casing below the seal or thimble plate and passes upward. The dust is precipitated on the inner surfaces of the tubes or bags. They are attached to a shaking device, usually connected at the top, which is operated periodically to shake the dust pack from the inner surfaces of the fabric.

The cloth-screen type collector is a refinement of the tube or bag type. In this type the filter fabric is applied over a series of rectangular frames which effectively support the cloth. The fabric covers both sides and three edges of the frame with the fourth

TABLE 1 — RECOMMENDED VELOCITIES FOR EXHAUST SYSTEMS CONVEYING DRY DUST

Material (dust)	Branch pipe velocity* lineal feet per minute			
	2500 to 3000	3000 to 3500	3500 to 4000	4000 to 4500
Abrasives	—	—	X	—
Asbestos	—	X	—	—
Buffing Wheels	—	—	—	X
Carbon and Coke	—	X	—	—
Cast Iron	—	—	—	X
Cement and Lime	—	—	X	—
Charcoal	—	X	—	—
Chrome Ore	—	—	—	X
Clay and Ceramics	—	—	X	—
Coal	—	—	X	—
Cocoa and Chocolate	—	X	—	—
Cork	X	—	—	—
Cosmetics	X	—	—	—
Cotton	X	—	—	—
Feeds and Grain	X	—	—	—
Flint and Feldspar	—	—	X	—
Flour	X	—	—	—
Foundry:				
Blast Cleaning (sand abr.)	—	—	X	—
Blast Cleaning (steel abr.)	—	—	X	—
Sand Handling	—	—	X	—
Tumbling Mills	—	—	—	X
Glass and Cullet	—	—	X	—
Granite	—	—	—	X
Grinders and Polishers	—	—	—	X
Gypsum and Plaster	—	X	—	—
Lampblack and Graphite	—	X	—	—
Leather	X	—	—	—
Limestone	—	—	X	—
Manganese	—	—	—	X
Marble	—	—	X	—
Mica	—	X	—	—
Ore (iron)	—	—	—	X
Oyster Shell (buttons)	—	—	X	—
Pigments	—	—	X	—
Plastics	—	X	—	—
Rubber Compounding	—	X	—	—
Sanders	—	—	—	X
Silica and Quartz	—	—	X	—
Slate	—	—	X	—
Soap	—	X	—	—
Starch	—	X	—	—
Stone and Rock	—	—	X	—
Sugar	—	X	—	—
Talc and Soapstone	—	X	—	—
Tobacco	X	—	—	—
Wood	X	—	—	—

* For average conditions of fineness and loading with normal temperature and moisture content. When applicable, state code requirements supersede the figures specified.

edge left open to form a flue for clean air outlet. The open ends of the screens are sealed to each other or to the collector casing to divide it into a dust side and a clean air side. The screen frames are connected to a shaking or rapping device for dislodging the dust pack from the cloth surfaces. The dust is collected in hoppers below the screens.

As the dust builds up on the cloth surfaces, collector resistance gradually increases. It is therefore important to keep cloth surfaces clean. With the more common collector arrangement, the intermittent type, the cloth is cleaned by periodic operation of the shaking device with the exhauster shut down. A cleaning period of five to ten minutes after each four to five hours operation is average.

In process applications where shut-down periods cannot be permitted, a continuous self-cleaning type must be used. This type uses a principle of reverse air flow for continuous cleaning of the cloth filters. This is accomplished by action of a traveling manifold which includes an integral reverse air blower which takes air directly from the clear air side of the collector. This manifold covers three vertical rows of cloth covered screen frames. The face of the manifold is covered with a flexible diaphragm, having a row of orifice openings at the vertical center line. The diaphragm is inflated against the grid wall under blower pressure and reverse air is blown through the center row of screens while the manifold blocks air flow through the rows on both sides.

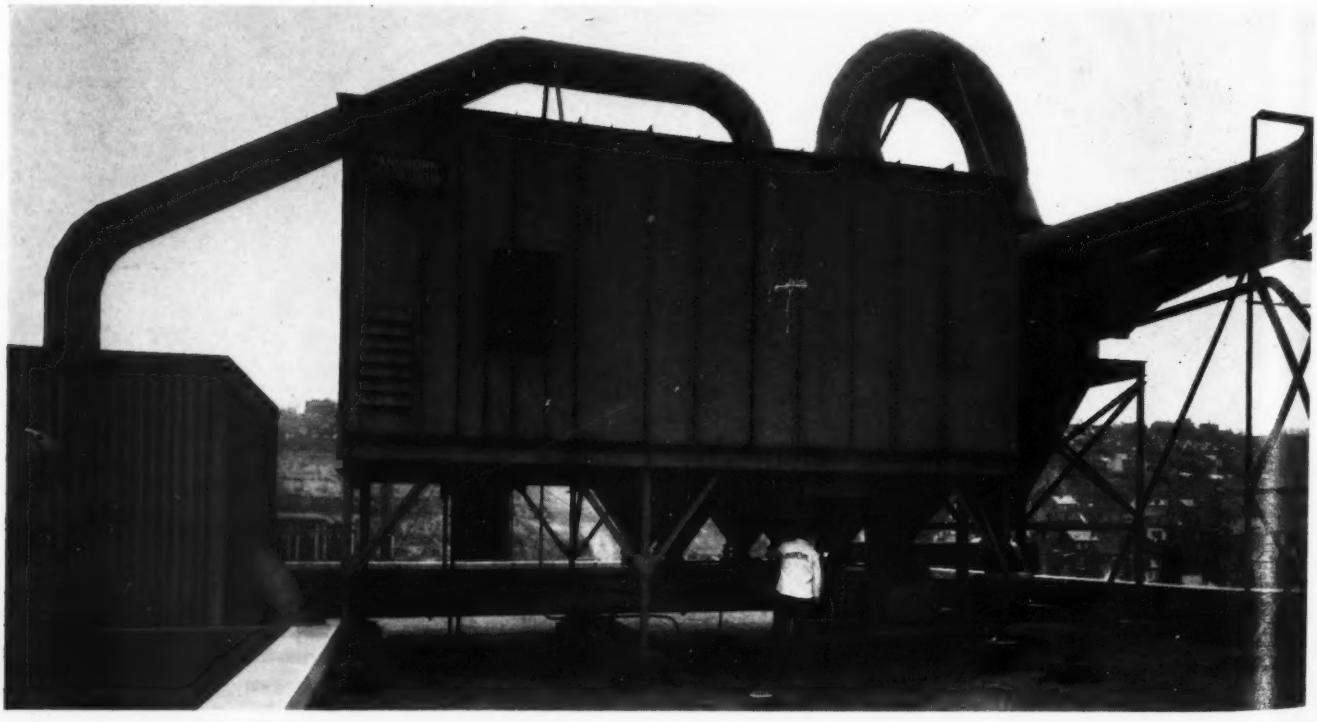
This arrangement blows the dust from the center row screens and allows it to drop to the hopper instead of being re-entrained, and at the same time prevents air short-circuiting. The blower motor in the traveling manifold is interlocked with the main exhauster motor to insure simultaneous operation.

Cloth Filter Limitations

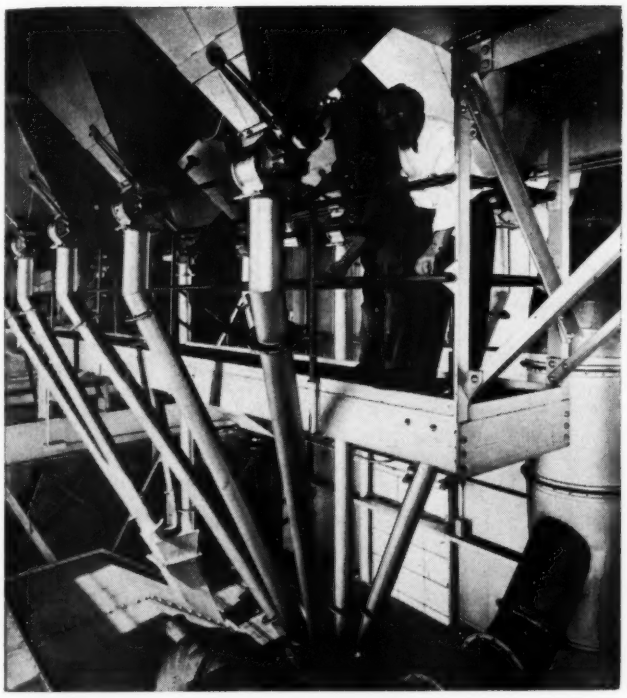
Properly applied and maintained cloth filters will provide effective suppression of finely divided, as well as coarse, industrial dusts, but there are several factors which must be given consideration in their application. The more important limiting factors are temperature, moisture, and chemical qualities of both the dust and the conveying air or gas. The limiting temperatures for the filter fabrics in most general use are approximately 175 F for cotton and about 225 F for wool. Some of the newer synthetic fiber fabrics will permit a considerable increase in practical operating temperature ranges. Improved chemical resistance is also possible through use of these new fabrics.

When containing moisture, the conveying air and collector temperature must be maintained above the dewpoint to prevent condensation which causes sludging of dust on the cloth surfaces.

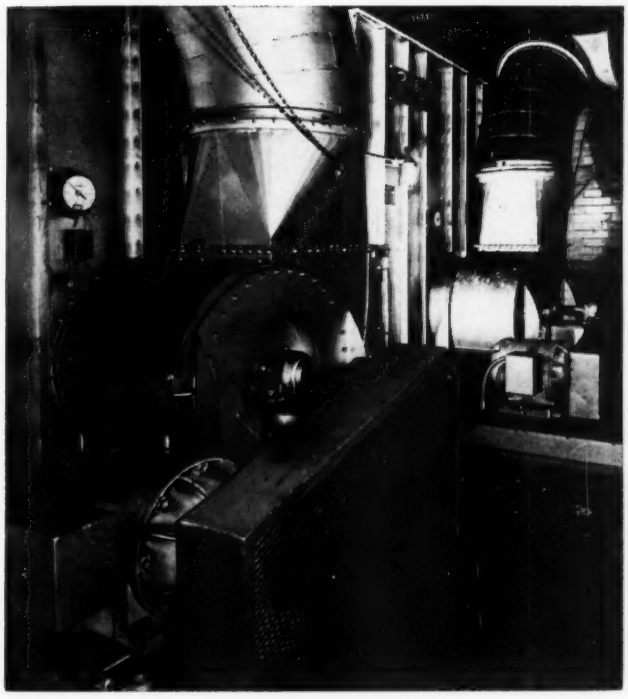
Factors governing the cloth filter recommendation for each application are the air volume handled; nature, characteristics and amount of material to be collected; and range of dust particle size and specific gravity. The size of a cloth filter is governed by consideration of these factors. The filtration velocity used with intermittent type collectors will vary with specific problems of average nature in the range of from 2 to 4 lineal fpm. This is more commonly termed "ratio," meaning 2 to 4 cfm passing



CLOTH SCREEN COLLECTOR RECOVERS GRAIN DUSTS AT THE NEW PITTSBURGH PLANT OF DUQUESNE BREWING CO.



CHUTES FROM COLLECTOR RETURN SALVAGED COAL TO CONVEYOR AT DETROIT EDISON POWER PLANT.



BELT-DRIVEN EXHAUST FANS FOR TWO 20,000 CFM CLOTH SCREEN COLLECTORS AT DETROIT EDISON.

each square foot of filtering area. With continuous type collectors, the ratio is frequently higher.

High dust loadings are reduced by presettling devices installed ahead of the cloth filter. Presettling is accomplished by a centrifugal or cyclone collector, settling or baffle chamber, or other devices effective for partial precipitation.

Exhauster and Drive

Exhauster size is determined by the total air volume to be handled and the total resistance of the system. This air volume is the sum of the volumes exhausted from the hoods, usually plus a 10 percent allowance for system leakages. The total resistance of the system is the sum of the hood entrance loss, maximum velocity head, frictional resistance of the most resistant branch including bends and entrance into main, frictional resistance of the main exhaust pipe, collector resistance including entrance and discharge losses, and frictional resistance of exhauster inlet and discharge piping.

Exhausters of the steel plate planning mill type are most commonly used for exhaust systems, particularly when handling dust through the fan. There are two general wheel designs available, the radial blade (paddle wheel) and the slow speed, or forward curved blade.

In suction type installations, particularly when using cloth filters with the exhauster handling cleaned air, higher efficiency fans similar to those for ventilating work are used, the more common designs being the multiple forward curved blade type and the backward curved blade, or high speed type. While these exhausters are similar in design to those used in ventilating and air conditioning, they are usually of heavier construction because higher pressures are required.

Although flat belt and chain drives are sometimes used to connect the drive motor, the multipleV-belt drive predominates because of low initial cost, minimum slip with short centers, and flexibility for speed changes. Direct driven exhausters are not advocated for industrial exhaust system applications since it is generally difficult to select a fan to meet specific requirements which would have an operating speed coinciding with standard motor speeds. There is the further disadvantage in that any change in the system's air volume or pressure requirements would necessitate a new special wheel or would require converting the fan to belt drive.

Correctly designed systems pay their own way both in tangible and intangible savings. Collected waste, better workmanship, unsoiled finished products, greater visibility within the plant, less frequent painting, and longer life of operating equipment are all specific savings which can be credited to dust control equipment.

1. *Industrial Health Engineering* by Allen D. Brandt. Published by John Wiley & Sons, Inc.

2. *Industrial Dust* by Philip Drinker and Theodore Hatch. Published by McGraw-Hill Book Co., Inc.

3. *Fundamentals of Design, Construction, Operation and Maintenance of Exhaust Systems.* Published by American Foundrymen's Society.

TABLE 1 — REVISED DUAL-PURPOSE REACTOR

Data	*Proposed reactor*
Purpose	Plutonium and power
Neutron energy	Thermal
Power:	
Heat	675 mw
Electric, net	125 mw
Materials:	
Fuel element	Hollow tubes, cooled internally and externally
Moderator	Graphite
Reflector	Graphite
Primary coolant	Sodium
Fertile material	U-238
Fuel temperature (max)	1100 F
Coolant inlet	300 F
Coolant outlet	825 F
Coolant velocity (maximum)	20 ft/sec
Flow rate	32,000 gpm
Primary pumping power (50% efficiency)	3 mw
Dimensions:	
Core	Octagonal prism, 15 ft high, 16 ft across flats
Reflector	20 in.
Shield	Concrete and iron
Thickness	8 ft
Secondary sodium system:	
Flow	32,000 gpm
Pumping power	2 mw

TABLE 2 — REVISED DUAL-PURPOSE REACTOR

Electric power costs (7500 hrs/year of operation)

	Proposed reactor	*Modern coal-fired plant*
Capital costs, 10^6	16*	22
Net output, kw	125,000	125,000
Cost, dollars/kw	130*	175
	mills/kwh	*mills/kwh*
Depreciation	3.47 (20%)	0.68 (2.9%)
Property taxes and insurance (2%)	0.35	0.47
Fuel cost	0.00	2.35 (coal, 23¢ per million Btu)
Operating cost	0.50	0.50
Total (exclusive of financing costs and income tax)	4.32**	4.00**

* The total cost of reactor plus power plant is estimated to be in the vicinity of $60 million. For plutonium production only, the total plant would cost about $16 million less.

** In normal utility practice, the additional cost of financing (including interest on borrowed money and return on capital) plus income taxes would be about 10 percent, thus increasing the total cost of the power from 4.00 to about 6.33 mills/kwh. If the additional costs for the proposed reactor turn out to be only 10 percent, the total power cost would be 6.05 mills/kwh.

Revised Atomic Reactor Data

NEW INFORMATION is available on the current thinking of those close to the subject of atomic reactor development. Tables 1 and 2 show revised data which presently appear more plausible to the Monsanto Chemical Company than previously released information (CONSULTING ENGINEER, JULY, 1953, pp 28 to 36). The data above represent figures directly applicable to the reactor part of the generating station. In Table 2, the cost of the power is based on the additional cost required ($16 million) to make a plutonium-producing reactor generate 125,000 kw of electrical power.

These data are still in the proposal stage. But to put atomic power off 30, 20, or even 10 years is too long in the view of some. Though no one is about to break ground — for very good reasons — the technology is well enough along in the minds of many people to support the belief that a power producing plant could be built soon.

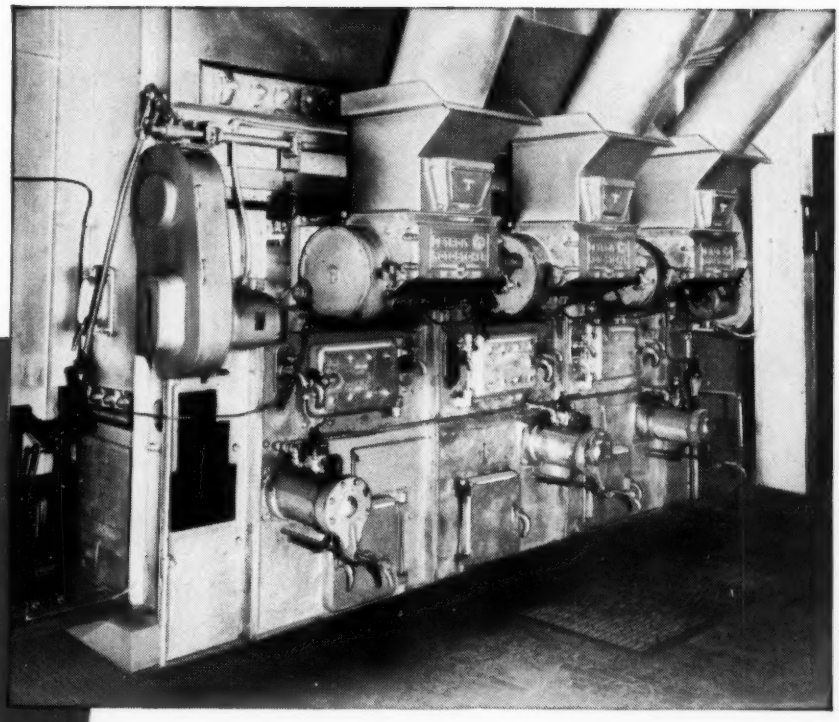
Deterrents

The present deterrents are four. The first is the law, which prevents private ownership of critical reactor materials. No private capital would commit itself to investments which would be dependent on fettered sources of vital materials. Secondly, final tests on current proposals would have to be proved out in an experimental model on a pilot plant basis first. This would make sure that technical and economic estimates are right.

Third, patent policy in the atomic field would have to be revised. Monsanto is one company that has spent some half a million dollars merely studying the feasibility of atomic power. This is admittedly an investment in research with no objective of developing patentable ideas. But if private capital is to invest in actual power-producing facilities, it will undoubtedly demand full advantage of the patent law to protect whatever competitive advantages it develops along the way.

Plutonium Demand

The fourth requirement is that the government must maintain its demand for plutonium for some thirty years — a period corresponding to normal utility amortization intervals. This is perhaps a transitory requirement since the sale of plutonium is presently required to help carry some of the reactor cost. As reactor technology advances — and it shows no signs of slowing — power may come cheap enough to provide all the revenue needed to pay for the reactor plant.



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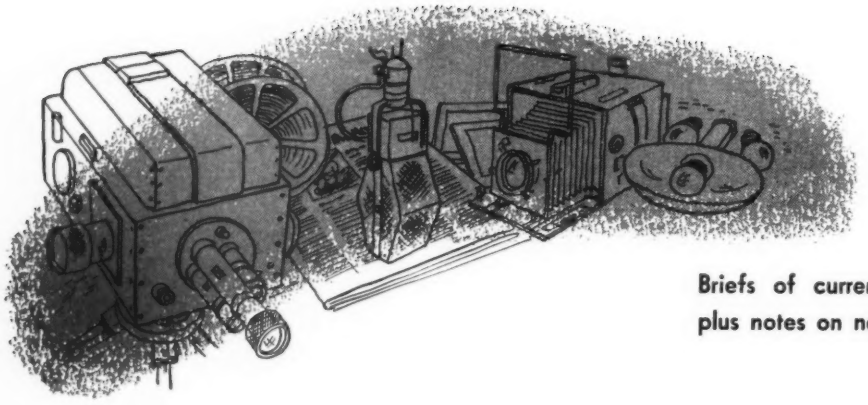
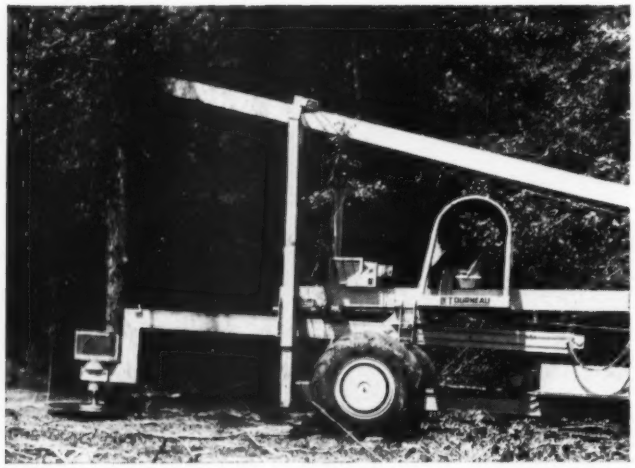


NEWS

Briefs of current interest to the consulting profession plus notes on new equipment in the field of engineering



Cost Per Acre Reduced by Mechanized Land Clearing

Clearing operations of 16,000 acres in preparation for a holding pool on the Sulphur River, part of the Lower Mississippi River Flood Control System, are proceeding at better than 2 acres per hour.

Key machine in the operation is an electrically-powered circle saw on a pivoting boom which will selectively cut all trees in a 250 sq ft area in front of the saw. An overhead pusher boom, which directs the fall of trees in parallel positions, makes checking and burning a simpler operation.

To reach out over streams, sloughs, or steep banks for trees not normally accessible to mechanized saws, a unit known as the Tree Stinger features a 34-ft telescoping boom which extends another 19 ft.

R. C. Letourneau, Inc., manufacturer of the new line of land-clearing machinery, expect the equipment to cut considerably the cost per-acre of clearing by replacing hand labor with mechanized power. Contractor for the job is Benson & Youngman, Muskogee, Oklahoma.

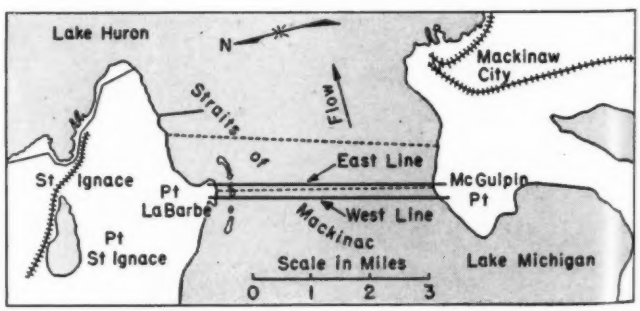
Industrial Fire Losses Mounting

Unless the continuing upward trend is reversed, fire losses for 1953 will total well above 1952's peak of $815 million. Mounting production and greater values exposed to fire contribute to the higher figures. But such losses would be even greater if it were not for major advances in fire prevention, construction, safety measures, and improved methods of fire fighting.

With the above facts in mind and believing that far too often, fire prevention and protection is an after-thought to a construction program rather than being engineered into the plant and its manufacturing process, U.S. Fire Protection Engineering Service, Inc., has been organized. Connected with no insurance company, equipment manufacturer, or construction contractor, the firm's announced aim is to assist in achieving and maintaining fire-safe and economically-insurable plant operation. Services will supplement existing fire protection engineering departments and insurance inspection services or fulfill these needs in plants lacking such facilities.

Another development in the fire-protection field is a fire-retardant paint, which, when exposed to flame, is said to discharge carbon dioxide and calcium chloride. The oil base, flat wall paint, known as Fyr-Kote, is manufactured by Morris Paint & Varnish Co. under license from the National Fire Retardant Corp.

Further fire control information is offered in the Booklets Section, starting on page 74 of this issue.



Big Pull Completed Across Mackinac

Five and one-half months have seen completion of the "Big Pull" — nearly 8 miles of 20 in. oil pipeline, welded in 16, 2500-ft sections pulled across the bottom of the Straits of Mackinac.

Originally estimated to require 2 years by the engineering firm of Merritt, Chapman, and Scott,

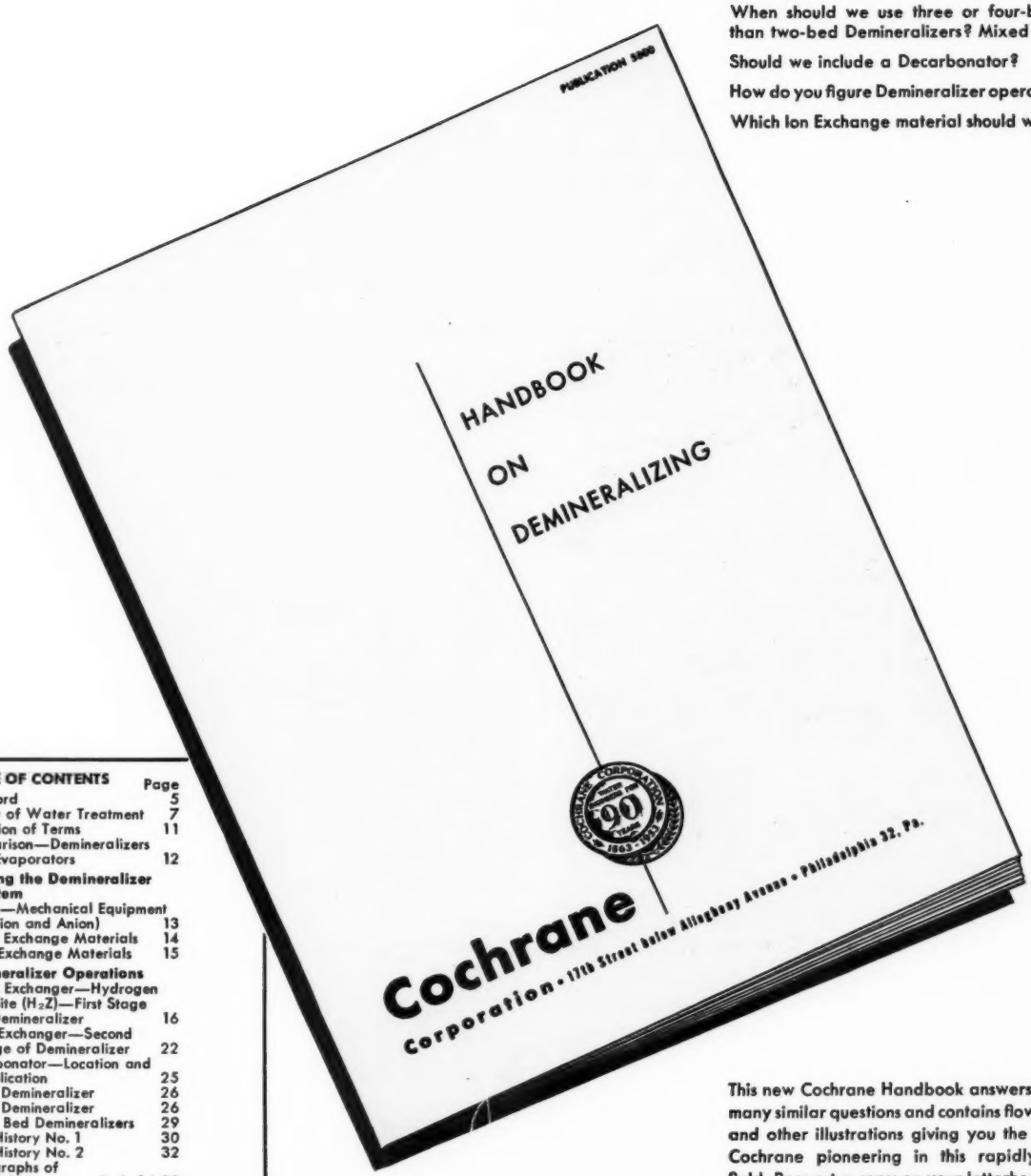
Why is Demineralization being selected instead of Evaporators?

When should we use three or four-bed rather than two-bed Demineralizers? Mixed Bed?

Should we include a Decarbonator?

How do you figure Demineralizer operating costs?

Which Ion Exchange material should we specify?



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This new Cochrane Handbook answers these and many similar questions and contains flow diagrams and other illustrations giving you the benefit of Cochrane pioneering in this rapidly growing field. Request a copy on your letterhead.

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Hot Process Softeners • Deaerators • Dealkalizers • Demineralizers • Reactors • Continuous Blow-Off • Specialties • C-B Systems

Big Pull Completed

—*Starts on page 54*

the 2 lines, lying up to 243 ft under water, were launched at Point La Barbe near St. Ignace, Mich. on the north shore and pulled across by winch to McGulpin Point near Mackinaw City — a distance of 20,000 ft.

Primary purpose of the new pipeline is to eliminate a serious winter bottle-neck in the delivery of crude oil to refineries in Sarnia, Ont. In the past, oil was piped to Superior, Wis. and then shipped by tankers to refineries, principally to Sarnia. But the Lakes are navigable only 7 months of the year. Transportation costs by pipeline are expected to be less and assure year-around delivery.

The remainder of the line (part of a 643-mile, $75 million project constructed by the Lakehead Pipeline Co., Inc.) will be a single 30-in. line, passing beneath 4 navigable rivers, 41 other rivers, and making 47 railroad crossings.

Electronic Brain Makes Completely Automatic Elevators Possible

An electronic brain, which makes operatorless elevator systems fully automatic, has been perfected by the Otis Elevator Co. Although present automatic supervisory systems coordinate the operation of a bank of elevators according to any one of a number of dispatching programs, an elevator starter must watch lobby traffic and the changing patterns of lights on his indicator panel to decide which program will best handle the prevailing traffic. He must then switch the supervisory system to the desired settings.

The new system, consisting of an electronic traffic analyzer and automatic program selector, was recently demonstrated for the first time. Shown in the illustration is the electronic unit that was used to control operation of a model incorporating flashing lights to simulate the movement of a four-car bank of elevators in a 10-story building.

In operation, the traffic analyzer continually records passenger calls and waiting time data, and the program selector automatically puts into effect the appropriate dispatching program and interval. When the traffic pattern changes, the control system promptly adjusts elevator service accordingly. The automatic system frees the starter of all responsibility for elevator supervision, thus permitting him to devote full time to giving information and providing the other personal services that tenants and visitors expect.

Larger Equipment Needed For Open Pit Mining

Larger and more efficient equipment is needed to reduce the cost of open pit mining, according to E. R. Dickie, General Manager of Bagdad Copper Corp., speaking at the Tractor Meeting of the Society of Automotive Engineers in Milwaukee.

Seven years ago, at the Bagdad mines, 2½ yd shovels loaded 15 yd trucks, and light drilling equipment with portable air compressors was used for all blast-hole drilling. Today, 6 yd all electric shovels, the largest trucks built carrying 50 to 60 ton pay loads, the biggest crawler type bulldozers manufactured, and Bucyrus self-propelled churn drills are doing the job at less cost. As high-grade ore deposits are depleted, even larger earth moving equipment will be necessary to handle lower grade ores.

Operating costs, for various sizes of equipment used by the Bagdad Copper Corp., show that unit costs are inversely proportional to capacities.

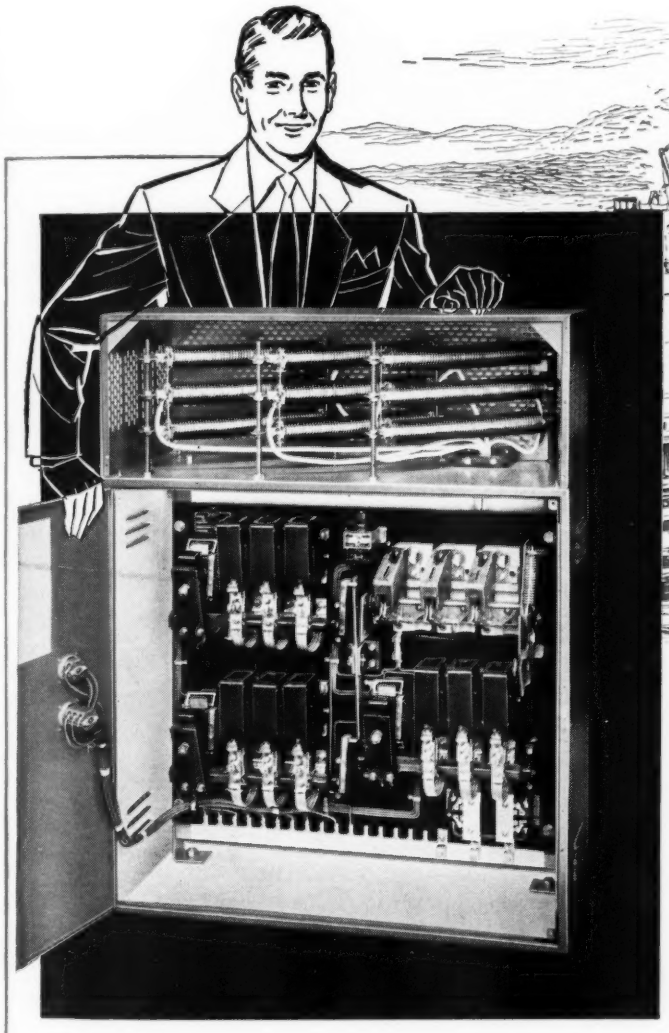
Equipment	*Capacity (yds)*	*Cost per yd loaded or hauled*
Diesel Shovel	2½	$ 0.0833
Diesel Shovel	3½	0.0601
Electric Shovel	3½	0.0323
Electric Shovel	4½	0.0252
Electric Shovel	6½	0.0213
Trucks	16	0.1086
Trucks	20	0.1016
Trucks	30	0.0466
Trucks	35	0.0450

Fast Analysis of Flue Gases Possible With New Method

There is an increasing amount of sulfur in fuels being used today, and its presence can have a serious corrosive effect on boiler tubes and breaching. A simpler and quicker means of analyzing flue gases was described by E. K. Diehl, associate fuel technologist, and R. E. Matty, senior chemist, at the Research Center of The Babcock & Wilcox Co., in a paper presented at the American Chemical Society, entitled "An Improved Method and Apparatus for the Determination of SO_2 and SO_3 in Boiler Flue Gas at any Operating Temperature."

Employing one standard solution of sulfuric acid which can be kept indefinitely without appreciable change in strength, the new method eliminates unstable standard solutions, which had been used previously, and requires only a small table, standard laboratory glassware, and a source of distilled water.

IT'S FEDERAL NOARK® MOTOR CONTROLS FOR THE PANAMA CANAL



ABOVE: View of the upper pair of the Miraflores locks and one of the control towers from which the new Federal Noark motor controls are operated.

AT LEFT: Interior view of one of the eight types of motor controls built for the canal project.

THE PANAMA CANAL is now undergoing an extensive modernization program. One phase requires new electric motor controls for the locks...and Federal Noark devices are being installed. These controls will assure the safe, efficient motor starting required for rapid and continuous canal service.

Special processes in the manufacture of these 398 motor controls were necessitated by the specifications. Wire insulation, for instance, and other parts likely to deteriorate under tropical conditions had to be protected against "attack by insects, especially cockroaches and termites," and made fungus-proof with suitable shellac. To accomplish this, Federal engineers treated each part separately before assembly.

Whether your control problems are simple or as complex as those for the Panama Canal, call in Federal Noark for the right solution.

Write Federal Electric Products Company, 50 Paris Street, Newark 5, N. J.

Plants at Newark, N. J.; Long Island City, N. Y.; Hartford, Conn.; Cleveland, Ohio; Gary, Ind.; St. Louis, Mo.; Dallas County, Texas; Los Angeles, Calif.; San Francisco, Calif.; Santa Clara, Calif. Affiliated plant, Toronto, Canada.

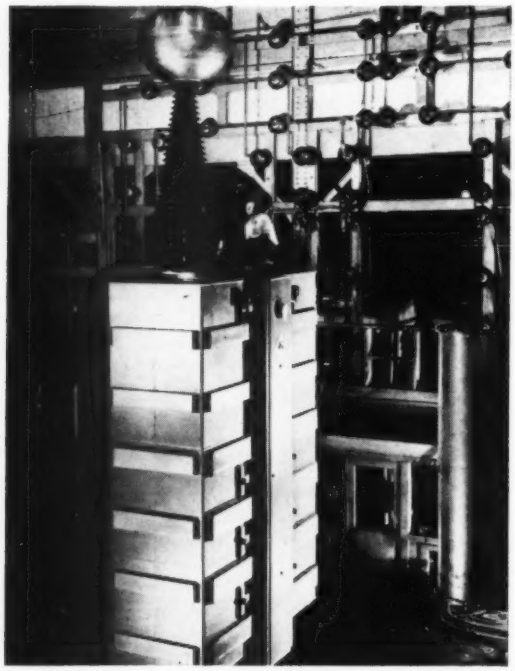
Federal Noark products: Stab-lok Circuit Breakers, Motor Controls, Safety Switches, Service Equipment, Industrial Circuit Breakers, Panelboards, Switchboards, Control Centers, Bus Duct — **Pacific Electric Manufacturing Corporation products:** High voltage circuit breakers and power switches ★ Sales offices in principal cities.

FEDERAL NOARK®

Flue Gases Analyzed Quickly

—*Starts on page 56*

Time required for the completion of such analyses has been reduced from one day to one hour, making it possible to collect samples during one test and obtain the results before a subsequent test on the same day. The improved method is regarded as highly important because it provides the boiler designer with information that can serve as a guide in determining the minimum allowable airheater temperature for a given fuel and method of firing.



Further Experimental Work Planned for 600,000-v Transformer

Built primarily to determine whether present basic data and calculating methods will be adequate to design power transformers at voltages far beyond those now being planned, the 600,000-v, single-phase power transformer pictured will be used for experimental and test work at Allis-Chalmers' West Allis Works.

In addition to 700-kv, low-frequency tests, the unit was given AIEE impulse tests of 1600-kv full wave and 1840-kv chopped wave. It is built to withstand 600-kv, 3-phase transmission line service with lightning arresters now available, or 880-kv service when suitable protective equipment is developed.

Since no standard terminal bushing capable of withstanding this extreme voltage was available, it was necessary to design and build one with an overall length of 17 ft including the 4-ft dia corona shield. Other new design features include very low oil requirement and final clamping of both core and coils after assembly in the tank.

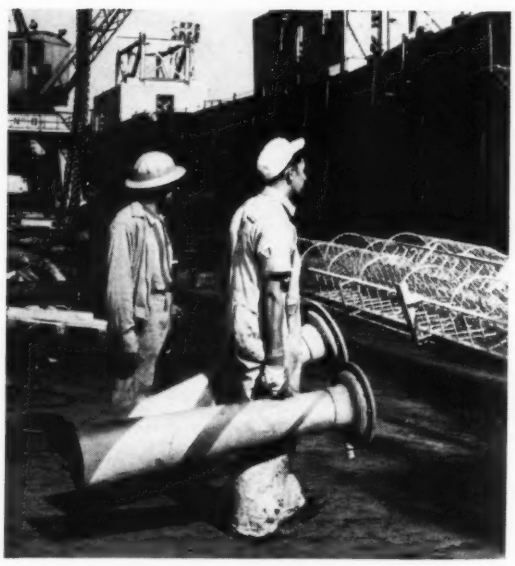
Experience gained in building and testing this transformer is being put to use in construction of the largest single-phase transformers in the United States — six 345-kv, 200,000-kva auto transformers for the Bonneville Power Administration.

Caution Urged in Use of Corrosion Control Devices

Serious damage to expensive equipment may result from the use of certain unproved devices for controlling corrosion and scaling according to the Inter Society Corrosion Committee. The committee, made up of some 35 delegates from technical societies in the United States and Canada, is sponsored by the National Association of Corrosion Engineers.

Caution is urged in the application of methods which are not based on any understandable scientific principle and which are promoted on the basis of testimonials from presumably satisfied customers, unsupported by quantitative data. Special attention is drawn to supposedly scientific explanations making liberal and incoherent use of such terms as catalysis, magnetism, electronics, and radiation.

In some cases recommendations are made by manufacturers that grounding wires of electrical circuits, if unfavorably connected to pipes in which the devices are installed, should be rearranged or connected elsewhere. The committee emphasizes that if electrical circuits are not grounded in accordance with the National Electrical Code, serious impairment of the safety of persons and property may result.



Portable Air Movers Operate By Compressed Air or Steam

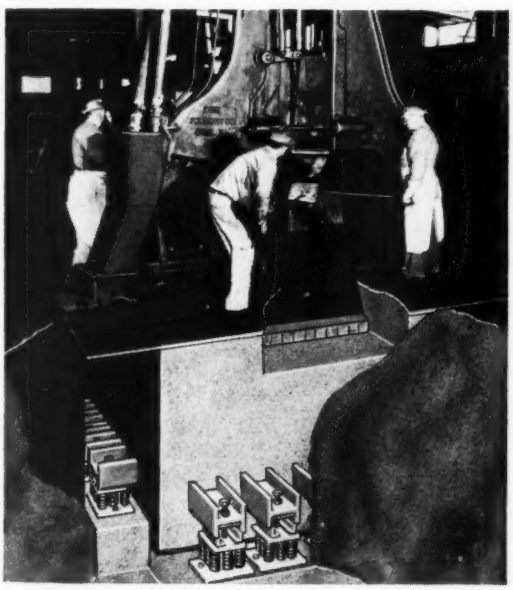
Portable air movers — venturi-type devices — used by the Paint Department of Dravo Corporation, Pittsburgh, have proved to be versatile, time-saving, and economical in providing ventilation where and when it is needed. Getting ventilation to a job site

now is a matter of a few minutes for one man, as shown in the photograph, instead of 20 minutes for several men, as was the case when 200-lb blowers had to be transported by crane for each painting job.

The units are used to remove dust-laden air from compartments of barges during power brushing prior to painting, to gas-free oil or gasoline barges brought in for repair or maintenance work, for exhausting noxious fumes generated when preservatives are applied to machinery prior to storage, and for interior paint-drying.

Known as MSA-Lamb Air-Movers, each unit weighs only 31 pounds, and can be operated on compressed air or steam.

Initial cost of the movers is reported to be about 1/10 that of an electrically driven explosion-proof blower and exhauster, and upkeep cost is practically negligible, since there are no moving parts to replace or maintain. The manufacturer is Mine Safety Appliances Co.



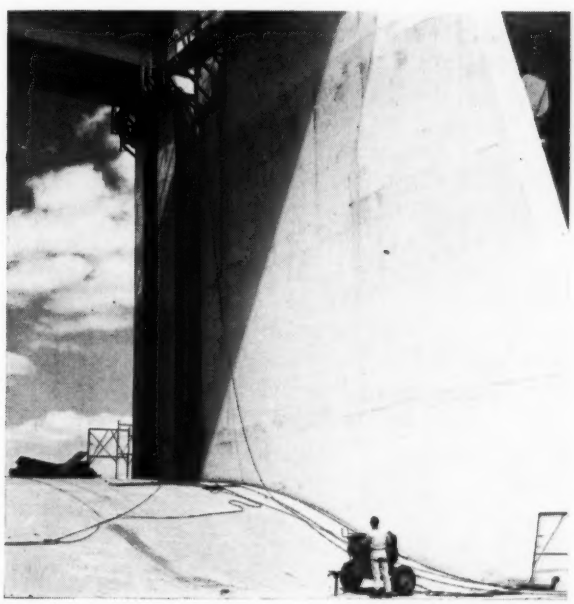
Modern Engineering Methods Overcome Noise and Vibration

Noise and vibration are two related and troublesome phenomena of the machine age. Three years ago a 3000 lb ram, double-frame steam hammer at the Earle M. Jorgensen Co. stood idle because each stroke of the hammer had created intense tremors that could be felt over a 500 to 700 ft radius. Aside from upsetting the efficiency of delicate machinery in the vicinity, and the annoyance of periodic rattlings and shakings, it soon became obvious that neighboring buildings would eventually suffer severe damage.

The existing foundation was replaced by one supported on specially designed Korfund Co. steel-spring Vibro-Isolators. Now, a coin placed on edge near the hammer will remain standing through continuous hammer operation, according to company officials.

Noise and clamor from metal stamping machinery, the problem at John Volkert Metal Stampings, Inc., was overcome by 320 Fiberglas Noise-Stop baffles hung vertically from ceilings. The installation, engineered and installed by Industrial Acoustics Co., Inc. has reduced noise by 50 percent.

The baffles are non-combustible, washable, moisture resistant, light weight, and may be painted without lowering the sound absorbing efficiency.

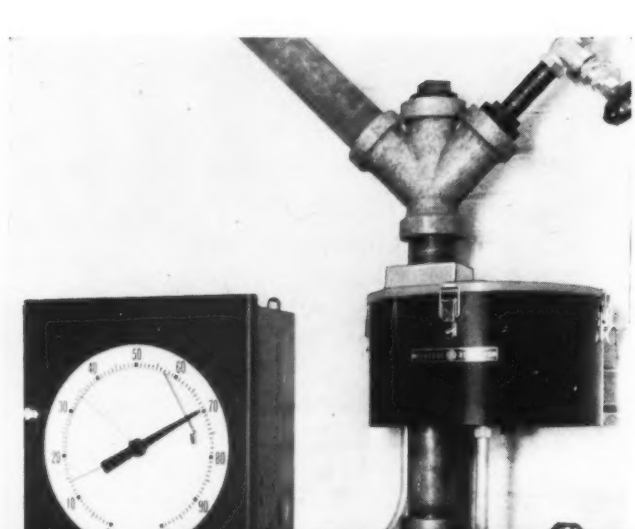


TWO NATIONS BEING WELDED TOGETHER

Dwarfed by a giant spillway door of the new Falcon Dam, is one of a number of engine-driven welders being used for construction. The dam, a joint venture of the United States and Mexico, when completed will harness the power of the Rio Grande River and provide water throughout the year for irrigation in the arid Southwest. The Acetylene Oxygen Co., of Harlingen, Texas, supplied General Electric welders and more than 50,000 pounds of electrodes for the project.

NEWS

—*Starts on page 54*



Turbidimeter Measures and Records Number of Suspended Particles

Engineers for plants using processes in which turbidity is a significant factor will be interested in a turbidimeter which continuously and automatically measures, and permanently records the number of particles suspended in liquids.

The theory of operation is that if a liquid has no suspended particles, all light is transmitted while none is scattered. As turbidity increases, more light is scattered and less is transmitted. The turbidimeter's detecting element is a single photovoltaic cell with current output proportional to the amount of light falling upon it. The light ratio is determined by computing voltage output of the photo cell when scattered light and then transmitted light are successively incident upon it.

According to the manufacturer, General Electric, the system is quite stable with respect to variations in photocell sensitivity, temperature, lamp brightness, line voltage, or color of the liquid.

With maximum operating pressure of 100 psi inside the sampling head, the recording turbidimeter has an accuracy of plus or minus 5 percent of full scale and a precision plus or minus 3 percent of full scale. Range is adjustable in the field from 0 to 25 to 0 to 10,000 ppm (silica scale). The sampling head requires 175-w, 115-v ac, and the recorder needs 55-w at 115-v ac. Cycle-time is 60 seconds.

Advanced Equipment Design Seen In West German Machine Tool Plants

West Germany now seems to have the best-equipped machine tool plants in the world but is suffering from a severe slump in orders, according to Christy A. Wiken, vice president of research and engineering at Rockwell Manufacturing Co.

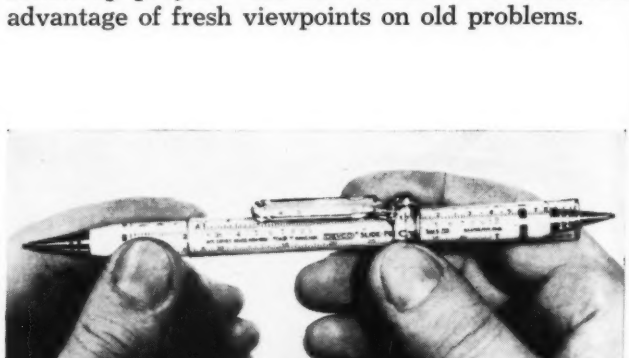
Leading German machine tool manufacturers have replaced their bombed-out plants and ruined machinery with superior equipment that incorporates the most advanced design ideas.

Discussing this new machinery, he mentioned as examples the boring and turning equipment in one German plant, which will accommodate parts over 52 feet in diameter — equipment probably unequalled anywhere else in the world, he believes.

Recently returned from a 3-month tour of 10 European countries, he added that a striking difference between European and American industry, is the apprentice system, which has gained new strength throughout Europe, especially in Germany and England.

Although the system varies from plant to plant, and from nation to nation, he said, the apprentices usually train for 3½ years under competent instructors, with separate facilities — sometimes entire buildings — set aside for them. At regular intervals they spend three months working in the production shops.

Throughout Europe, Mr. Wiken found increased interest in industrial research and a plentiful supply of scientists and designers to carry it out. Because the salaries of these experts are less than those expected by their American counterparts, he said, American research institutes are beginning to build laboratories abroad, where they can better afford follow-up projects and can achieve the additional advantage of fresh viewpoints on old problems.



Handy Clip Pencil Incorporates Slide-Rule Scales

Designed for the busy engineer, estimator, or contractor, one handy instrument, the slide-rule pencil, calculates, magnifies, and also writes in two colors.

Designed by the Device Development Co., it incorporates a fine print magnifier, depth gage, detachable ruling edge, and a plain and enlarging cursor for the slide rule's 9 scales.

Only 6½ in. long, its scales are permanently marked by a debossing process.

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Horizontal Type

Ceiling suspension type with heavy duty welded steel fin-and-tube heating element. The rugged arc-welded construction outperforms and outlasts heating elements made of thinner non-ferrous metals. Avoids their expansion-contraction faults, yet has the same BTU efficiency. Ten basic sizes with capacities from 30 Mbh to 490 Mbh. Totally enclosed motors. (Extra heavy non-ferrous coils also available.)

Vertical Projection Type Also Available

For efficient heating from high-ceiling areas—for door heaters over small openings—or where the horizontal type is not applicable. Ten basic sizes; capacities from 27 to 332 Mbh.

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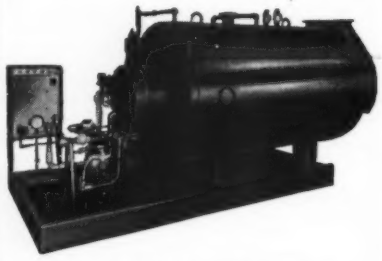

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THIS MAGAZINE IS OUR RECOMMENDATION

MEN IN ENGINEERING

★ John I. Thompson & Co. announces the election of Robert E. Fagley as vice president and engineering director (Management Engineering). With Fagley, the company's principal engineering officers include John I. Thompson, president and chief engineer; Owen F. Keeler, Jr., vice president and engineering director, and Max T. Smith, Jr., also vice president and engineering director.

★ Arthur D. Little, Inc., will open a new midwest branch office in Chicago with John R. Kirkpatrick in charge. It will be located in the Board of Trade Building, Room 3832, and will maintain a staff to carry out technical-economic, technical-audit, and market-research surveys in the midwest area.

★ George W. Llewellyn is named the manager of the new H. K. Ferguson Co. Western District office at 74 New Montgomery Street, San Francisco. The new office is equipped and staffed to offer complete engineering services, and includes purchasing, estimating, accounting, and sales departments. Announcement is also made of the formation of H. K. Ferguson Company of Canada, Ltd., with headquarters in Dominion Square Building, Montreal, Canada. O. F. Sieder, executive vice president and general manager of the Cleveland firm is president of the Canadian company. E. A. Charlton, of Montreal, is vice president and general manager. Other officials are John B. Kirkpatrick and W. N. Thompson, both vice presidents, and F. H. Maag, secretary-treasurer.

★ Wm. G. Hamlin, a sanitary engineer and specialist in industrial waste-control engineering, joins the staff of the Ohio River Valley Water Sanitation Commission. He formerly was associated with the Proctor and Gamble Co. where he was engaged in the development of waste disposal measures at various plants of the company.

★ Gordon R. Molesworth, assistant to the manager of Oak Ridge operations for the Atomic Energy Commission in charge of public relations, is named director of the Nuclear Energy Information Division of Bozell & Jacobs, Inc., New York.

★ Dr. Joseph Lichtenstein, formerly a consulting engineer in the heat transfer and hydraulics fields, is named eastern district manager for the Santa Fe Tank & Tower

CUTTING COSTS

Five of the eight members of the Industrial Engineering Dept. of Rockwell Mfg. Co. are shown revamping an assembly operation. (See "The Assembly Problem," page 35). Left to right are M. Meeder, H. Zimmer, Jr., K. W. Hutchins, manager of the dept; C. Kunkle Jr., and Ralph Day.

TWO CLYDE MODEL 24-E-115 WHIRLEYS at Kerr Dam, Va., each with capacity of 30 tons on boom, 10 tons on jib.

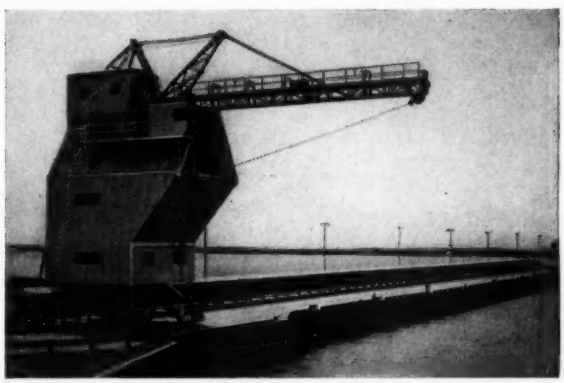
Strong-arm tactics on the Roanoke

Reaching for the sky at new Kerr Dam built by the Corps of Engineers on the Roanoke River in Virginia is a habit with this husky pair of Whirley gantry cranes made by Barium's Clyde Iron Works, Inc., Duluth, Minn.

Equipped with 100-ft. booms and 15-ft. jibs, the "Whirleys" poured concrete and handled other materials across all but the extreme ends of the 22,285-ft. dam, longest in the U. S. When complete, 144-ft. high Kerr Dam will back up an 83,200-acre "pond" for flood control, power generation and recreation.

These long-armed giants are samples of the complete line of construction machinery and materials you can get from Barium — power hoists, derricks, builders' towers, as well as structural steels, fabricated forms and fasteners of every type. You get what you want in a hurry, too. Barium's 16 companies function as an integrated unit that supplies engineering assistance, controls quality and speeds delivery . . . taking a load of detail work off your shoulders.

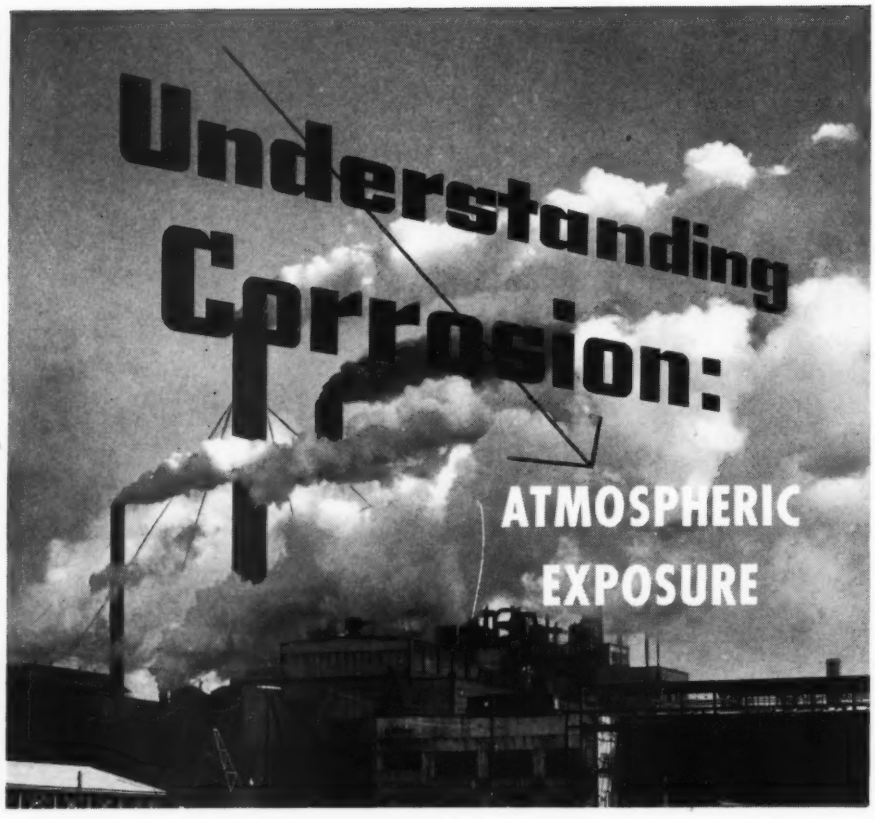
All this is at your disposal right now. Write Barium Steel Corporation, 25 Broad St., New York 4, N. Y.



NEW CLYDE ORE UNLOADER on duty at a southern port. Unloading bauxite ore from ship to conveyor belt, this mechanical "stevedore" digs at a 300-ton-per-hour clip.

3.39

BAYONNE BOLT CORP • CENTRAL IRON AND STEEL COMPANY • CHESTER BLAST FURNACE, INC. • CLYDE IRON WORKS, INC • CUYAHOGA SPRING COMPANY • EAST COAST AERONAUTICS, INC • ERIE BOLT AND NUT COMPANY • GEOMETRIC STAMPING CO • GLOBE FORGE, INCORPORATED • INDUSTRIAL FORGE & STEEL, INC. • JACOBS AIRCRAFT ENGINE CO. • KERMATH MANUFACTURING CO. • KERMATH LIMITED (CANADA) • PHOENIX BRIDGE CO. • PHOENIX IRON & STEEL CO. • WILEY MANUFACTURING CO.



The extent to which metal will corrode in atmosphere — or even whether it will corrode at all to any appreciable degree — is determined primarily by the moisture content of air. While deterioration at normal temperatures and humidities of less than 35% is so slow as to be almost negligible, the rate accelerates rapidly beyond a critical point of approximately 65%. This activity is intensified when such contaminants as hydrogen sulfide or sulfur dioxide are absorbed from industrial atmospheres. Impingement of solids, which tends to hold this acid film in contact with metal, localizes and further advances corrosive attack.

When exposure to atmosphere includes also exposure to sunlight and to the variables of weather, the situation becomes more complex. Such factors as the composition of metal and of the protective rust film that forms upon it, the length of time surfaces are wet, the extent to which they retain moisture, and whether they may be bared intermittently by heavy rainfall are influential in determining metal life.

An understanding of the mechanism of corrosion in all of its varied phases is an obvious requisite to prescribing methods of control. Thirty-five years' study and evaluation of industrial corrosion problems and the formulation of protective coatings to meet them has taught us something about corrosion and the ways in which it may be checked successfully.

We are ready to share that knowledge with you in an analysis of any metal-maintenance problem you feel requires the *different* approach of considered engineering judgment . . . to give you a recommendation you can be sure is technically correct and practically workable — for quality protective surfacing that is right for you because it is individually job-selected to meet your service specifications.

MAINTENANCE FOR METAL

THE DAMPNEY COMPANY

160-1 HYDE PARK, BOSTON 36, MASSACHUSETTS

MEN

—Starts on page 62

Co. He also is chairman of the Code Committee on Atmospheric Water Cooling Equipment of ASME. Jack Slough, noted for his work in cooling tower research and development, joins the company as assistant chief engineer.

★ Charles E. Robbins, formerly vice president of Bozell & Jacobs, Inc., is appointed executive manager of the Atomic Industrial Forum, Inc. Walker L. Cisler, president of the Forum, also announces the appointment of Oliver Townsend, formerly the assistant to the chairman of the Atomic Energy Commission, as assistant executive manager and secretary of the Forum. (CE, May '53, page 64.)

★ The American Society of Civil Engineers announces the election of Daniel V. Terrell as president. He is Dean of the College of Engineering, University of Kentucky, and will be installed Oct. 21 at the Society's annual meeting, to be held in the Statler Hotel, N. Y. Two newly-elected vice presidents are Enoch R. Needles for Zone 1 and Mason G. Lockwood for Zone 4. New directors are Wm. S. LaLonde, Oliver W. Hartwell, Thomas C. Shedd, Samuel B. Morris, Ernest W. Carlton, and Raymond F. Dawson.

TERRELL

JOHNSON

★ Herbert G. Johnson is elected vice-president in charge of sales of The Kuljian Corporation. Formerly general manager of the Heat Transfer Division, C. H. Wheeler Mfg. Co., he has specialized in the applications of heat transfer equipment and stainless steel processing equipment.

★ Frank R. Benedict is appointed staff engineering manager on the staff of H. E. Seim, vice president and general manager of the Westinghouse Sturtevant Division and Air Conditioning Division, and The Bryant Electric Company, a subsidiary of the Westinghouse Electric Corp. Benedict is a national director of the AIEE.

★ Appointment of A. D. L. Orefice as chief engineer and G. F. Ross as assistant chief engineer of the Coke Plant Dept. of Koppers Co., Inc., is announced. Orefice will di-

STOWE Stokers

9 units installed under existing boilers at U. S. STEEL'S Clairton Works reduce smoke and fly ash help make a cleaner, better Allegheny County

● **U. S. STEEL** is justly proud of the contribution it is making in its program of reducing smoke and fly ash in this area. And we, of The Johnston & Jennings Co., are proud of the performance of the 9 Stowe Stokers recently installed in the Clairton Works.

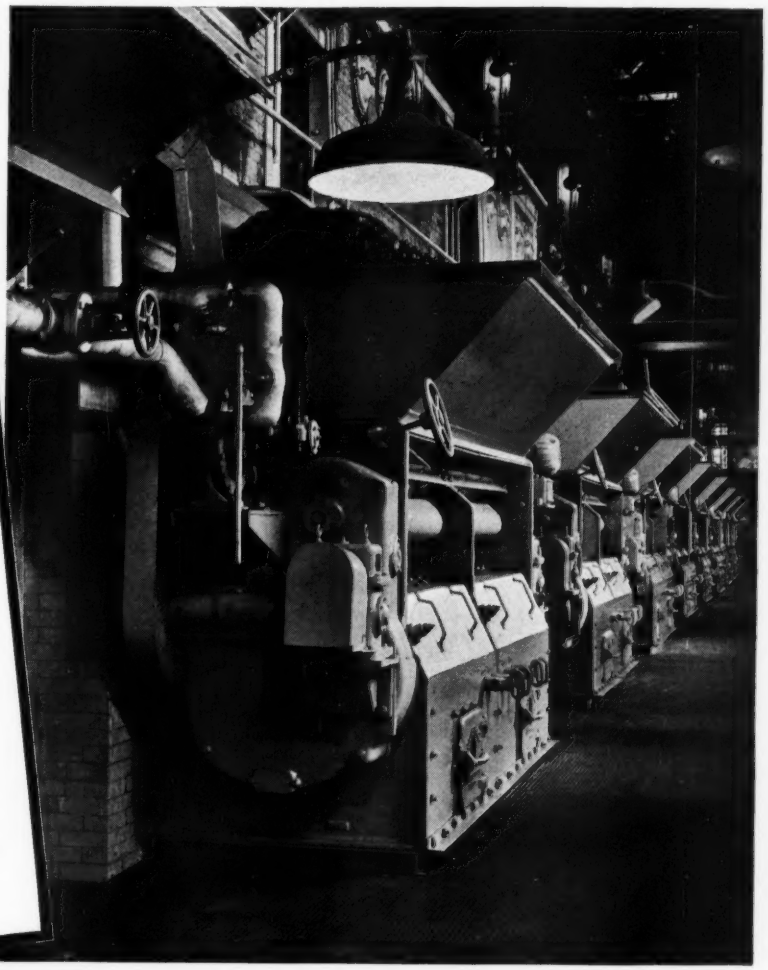
THESE 9 STOWE STOKERS, each installed under an existing boiler, reduced a smoke and fly ash problem. Stacks of these same boilers are now conforming fully to the requirements of the Allegheny County Smoke Control Ordinance — without requiring the installation of any smoke or fly ash collectors.

PRODUCE MORE STEAM

The Stowe Stokers increased the output of the 9 boilers from a maximum of 16,000 to 18,000 lbs. per hour each to 40,000 lbs. per hour each — more than double — and at the same time effected a very material cut in steam costs.

PROVEN DESIGN

Correct burning rates per sq. foot of grate area; — even depth of fuel bed from side to side and front to rear; — and uniform air distribution — no suspension burning — are some of the reasons Stowe Stokers perform so well. Send for Bulletin No. 501. Let us help **you** eliminate smoke, increase the steam output of existing boilers, and cut steam costs in **your** plant.



"More Power to You" with **STOWE Stokers**

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Reliance EYE-HYE can now operate auxiliary alarms

THE highly accurate EYE-HYE manometric gage has supplied reliable boiler water level indication on panel boards or other remote locations for more than 15 years. Now you can have auxiliary light signals or audible alarms anywhere in your plant, dependably operated by an electronic hook-up with the EYE-HYE.

Probes extending into the window unit and the calibrating tube complete an electrical circuit at the level of the indicating fluid. The signals or alarms coincide exactly with the reading in the always-accurate EYE-HYE. This new facility, added to the popular EYE-HYE, in no way interferes with the reliable operation of the remote gage.

With a two-light Levalarm Light Indicator, the red light warns of dangerously high or low water levels, the green light indicating a safe level. Vibratory electric horns or bells can be used in addition or instead of light signal.

Increase the safety of your water level control. Write for more information on the EYE-HYE with auxiliary alarms.

THE RELIANCE GAUGE COLUMN COMPANY • 5902 Carnegie Avenue • Cleveland 3, Ohio

MEN

—Starts on page 62

rect the engineering design on all chemical recovery coke plant projects of Koppers Engineering and Construction Div. Construction of a plastics development plant at the site of the Kobuta chemical plant of Koppers Co., Inc., is announced. Design and erection of the new facilities will be done by the Chemical and Gas Dept. of Koppers Engineering and Construction Div.

★ David Walters is appointed chief industrial engineer of Bohn Aluminum and Brass Corp. He will serve on the staff of the operations manager, G. A. Schwenk, and will make his headquarters at the main office in Detroit.

WALTERS THOMAS

★ Wm. J. Thomas, general sales manager, is appointed general manager of the Tubular Products Div., The Babcock & Wilcox Co., and Paul J. Utnehmer, works manager, is named to the board of directors of the division.

★ J. Carlton Ward, Jr., president of Vitro Corporation of America, announces the election of Geo. White, Jr., to executive vice president.

★ Out of 75 factory buildings completed in the Greater Cleveland area during the years of 1951 and 1952, the foundry erected for the Ford Motor Company was selected by the Cleveland Chamber of Commerce to receive a medal of merit as the most outstanding in the large

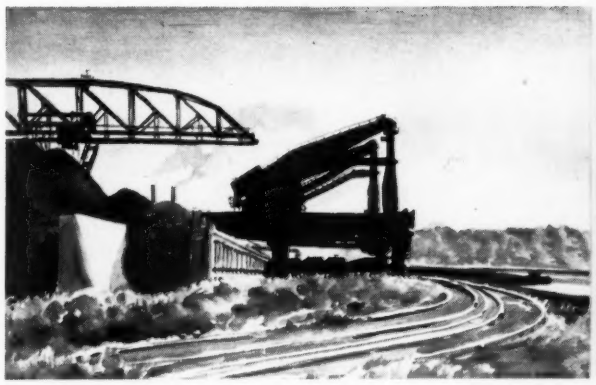
factory building class. The structure is part of an extensive development comprised of an engine plant, boiler plant and auxiliary buildings all of which were designed by F. A. Fairbrother—Geo. H. Miehls, Architect & Engineer, with the Albert Kahn Organization of Detroit as Consultants.

★ Lawrence E. Blazey, who recently joined the consulting firm of Grothe & Swanker, Inc., of Cleveland, Ohio, is, in himself, a particularly good demonstration of the fact that art and science can join hands to produce better industrial products.

Blazy, who is well-known in both art and industrial circles, will have charge of appearance design and product styling for clients of the firm. He is a graduate mechanical engineer as well as a graduate of the Cleveland School of Art. He has styled many nationally known products ranging from machine tools to home appliances. He is also well-known for his work in ceramics and architectural design, having designed and erected the first steel panel modern home of all welded construction in 1942.

Blazey's paintings and ceramic works have been exhibited in major museums throughout the country. One of his water-colors, "Highlift Unloaders at Cleveland Dockside," is reproduced here.

The firm of Grothe & Swanker, Inc. has a consulting staff qualified to take on and solve problems in mechanical, electrical, chemical, and industrial engineering.



★ Merle Newkirk, a member of The Dow Chemical Company's Power Dept. at Midland for the past 38 years, has relinquished his responsibilities as dept manager. However, he will continue to serve the dept as a consultant. Macauley Whiting is appointed Midland Div. power manager, with duties centered mainly in the fields of business and economics, and Leo L. Moran is named operating manager in direct charge of all Midland power operations.

★ Alton D. Anderson is the new chief engineer of the Cook Research Laboratories succeeding D. C. McDonald who resigned. Earl L. Washburn is appointed technical head of the Systems Development Section of this division of Cook Electric Company.

★ Ace Engineering & Machine Co., Inc., and RFI Shielded Enclosures Corp. announce their amalgamation. Richard B. Schulz, Electro-Search, former engineering consultant to Ace, will now serve as consultant to both companies. Both companies are engaged in the manufacture of shielded enclosures.

★ Irving D. Canton who recently returned from four years production experience in South America, where he designed, supervised construction of, and operated several chemical plants, is appointed chief of Latin American operations for the international dept of Armour Research Foundation. His first assignment takes him to Uruguay.

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MARKETS: Industrial and consumer market data.
LABOR: Availability, skills and rates.
POWER AND FUEL: Character and cost at any point.
AVAILABLE BUILDINGS: Types, condition, facilities and terms. Confidential.
SITES: Availability, size, character, installed services; photo and maps. Confidential.
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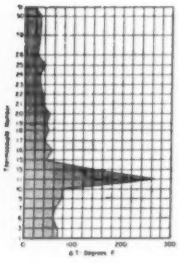

The Optimum Boiler Water

—Starts on page 28

the point at which feedwater is introduced. To meet this problem in low and intermediate pressure boilers, organic dispersives, chiefly tannins and derivatives of lignin, have been applied with good results in many cases.

One difficulty when using dispersives is that they often merely delay the process of precipitation of calcium phosphate, so that the sludge which would normally be deposited in the downcomers accumulates instead on a strongly-heated wall tube farther along in the circuit. Even with lignin derivatives specially processed to provide stability at high temperatures, the sludge deposits have been found to contain 15 percent or more of organic material. In extreme cases, the decomposition product intermixed with the usual calcium phosphate and magnesium silicate sludge has been chiefly elemental carbon, as if the lignin had been progressively charred in the hot concentrating film of boiler water next to the surface of the tube.

Silica is another sword which cuts both ways. Almost universally considered objectionable in high pressure boilers delivering steam to turbines, it has proved itself most useful in cleaning up stubborn sludge problems in boilers up to 600 psig. Its practical value is in causing magnesium ion to be removed as favorable magnesium silicate rather than the adherent magnesium phosphate[15].

Other examples could be cited at length. Ammonia, rigorously excluded from some systems because of its corrosive action on copper alloys, is deliberately introduced in other systems to reduce corrosion in return lines carrying condensate. Sulfite, widely employed as a chemical scavenger to remove dissolved oxygen, can decompose at hot spots in a boiler to produce sulfide, readily detected in some cases by the odor at the vent of the air ejector. Sulfate has been added to boilers by the trainload over many years in the hope (since shown to have been unfounded) that it would avert caustic embrittlement. Instead, it has loaded superheater tubes with deposits or has required an increase in blowdown to keep dissolved solids below the range at which objectionable carryover would occur.

Pure Water

Many mechanical engineers, who have looked hopefully for the development of a standard safe boiler water, are swayed by the alluring idea of "pure" water—water prepared by evaporation, deaerated mechanically and untreated with any chemical. Such a water is considered necessary in a once-through boiler, where any substance initially present in solution must either deposit as the water is progressively converted into steam or must be carried along by the steam. For natural-circulation and forced-circulation boilers in which part of the water is recirculated, the idea also seems attractive at first glance. However, there is a serious defect of "pure" water in that it produces a relatively low pH range of about 8.5-9.0 in the boiler. The ordinary low carbon steel used in boiler construction cannot develop as protective a film of iron oxide within this range as it does at a pH of 11 or above.

The Hydroxyl Ion

Deionization promises to increase the use of substantially pure water for power boiler makeup, with a possible trend toward utilization of "pure" water with its resultant low pH in the boiler itself. This probability makes consideration of the part played by the hydroxyl ion in the boiler water particularly important. Steel, particularly steel subjected to local stress, is vulnerable to attack by "pure" water, and is not adequately protected by its oxide film until some appreciable concentration of free sodium hydroxide is present in the boiler water.

FIG. 6—A ROOF TUBE FROM A UNIT OPERATING ON "PURE" WATER FAILED AT THE BOTTOM OF THE BEND.

Typical cracks attributed to the combined action of stress and corrosion by substantially pure water were found in the 1400 psig boilers at the Edgar Station of Boston Edison Co. during the period from 1936 to 1938[16]. The most serious were in the wall of the drum forming part of the feedwater inlet. Cracks also were observed in the lower connections of the water columns and in the pockets formed at the bottom of flanged connections at the inlet and outlet of the superheater headers. These locations are significant because although the pH value of the water in the drum ranged from 11.0 to 11.7 that of the feedwater entering the drum, and in contact with the steel which was attacked, varied only from 6.9 to 7.2. Condensed steam returning to the drum through the lower connection of the water column would presumably have shown about the same pH value, as would any condensate trapped in the flanged connections of the superheater whenever the boiler was taken out of service.

A striking example of selective corrosion in which stress probably played a part is shown in

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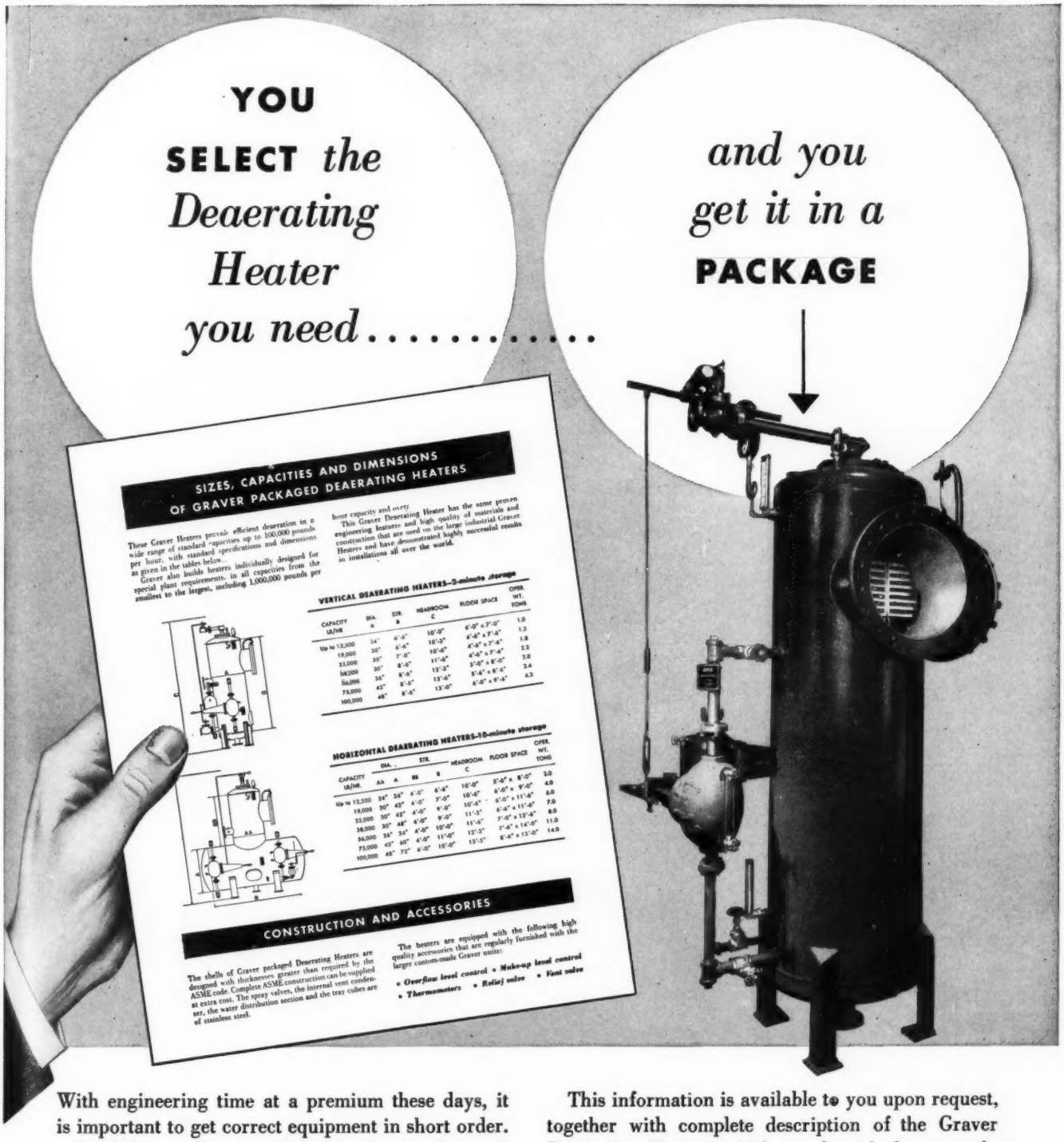
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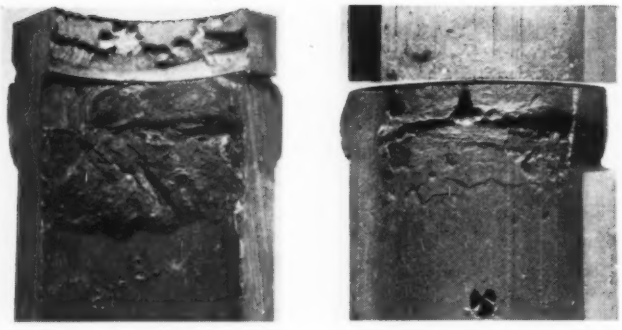

FIG. 7—LEFT. WITH ONLY CAPTIVE ALKALINITY, THIS WELD CORRODED DEEPLY IN THREE WEEKS. RIGHT. WITH CONTROL LIMITS OF 30 TO 50 PPM OF FREE SODIUM HYDROXIDE, WELD SHOWS LITTLE EVIDENCE OF ATTACK.

Fig. 5. This shows a piece of the single tube of a small once-through, forced-circulation boiler. The partially studded tube was coiled into a helix, the studs providing a support for refractory which formed the wall of the cylindrical furnace. Attack on the inner surface of the tube occurred particularly on a spot under each stud projecting inward toward the furnace.

Metallographic examination showed normal microstructure in the steel except where each stud had been spot-welded to the outer surface. Under each stud there was a zone which showed evidence of having cooled slowly from a high temperature, but this extended less than half way through the tube wall. It is probable that residual stresses in the steel resulting from the spot-welding and bending may well have been aggravated in service by the localized high heat input to the portion of the tube under each stud, the stud providing a conduit for transfer of heat in contrast to the refractory surrounding it.

One unusually definite example is afforded by a central station which operated on "pure" water for many years. An 850 psig boiler installed in 1940 experienced corrosion and failures at welds in wall tubes in 1947. Two more boilers, placed in operation in October, 1949, suffered serious damage within 18 months when roof tubes failed where they bent upward into the drum. Only the tubes in the third of three rows entering the bottom of the drum were attacked. Tubes in this row were bent slightly more than those in the other two rows and differed from them also in having heavy fins welded along each side to support refractory.

The first failure is shown in Fig. 6. Metallographic examination revealed that internal corrosion over the bottom half of the surface had been followed by the intergranular damage of hydrogen embrittlement with ultimate cracking, particularly along the line of fins. There was no evidence of overheating. Since dissolved oxygen frequently has been blamed for any type of corrosion in boilers, it is interesting to note that continuous records on a Cambridge meter showed no oxygen in an amount measurable by this instrument. Thus the attack on the steel must be attributed to the effect of local stress and the inability of the steel to form a protective film of oxide when in contact with boiler water in the low pH range of 8.7 to 9.6.

"Captive Alkalinity"

Even among plants maintaining a controlled alkalinity in the boiler water, there has been a "flight from the hydroxyl ion" during the past 15 years for boilers operating at pressures of 1200 to 1400 psig and higher. One example is the Port Washington Station of what is now the Wisconsin Electric Power Co. In 1937, the plant suffered extensive corrosion along the ceiling of the inclined tubes forming the screen across the bottom of the furnace in a 1300 psig boiler[17]. When this occurred, the alkalinity of the boiler water was decreased until it was only slightly greater than that produced by 60 ppm of disodium phosphate so that no free sodium hydroxide was present. The pH value with this control averaged approximately 9.6[18].

Emphasis upon maintaining only "captive alkalinity" has continued to the present time. A curve[19] of pH as a function of concentration of trisodium phosphate was published in 1942 which recommended that boiler water be controlled so that pH and phosphate content would not exceed indicated limits. The purpose of this was to avoid any chance of caustic embrittlement where boiler water might concentrate in a capillary space, and in many plants the results have been satisfactory.

However, records show that Port Washington did not prevent but merely retarded damage to the floor screen tubes by eliminating free sodium hydroxide from the boiler water. After 2½ years under this control, replacement of many tubes was again necessary as a result of internal attack[20]. In other plants[21] where the pH of the boiler water has been carried below 10.5, steel has been attacked at field welds and other points of localized stress just as in plants which operated on "pure" boiler water with still lower pH values.

Some particularly interesting evidence is available from another case in which 1400 psig boilers had been operated with only the "captive alkalinity" of phosphate in the boiler water. Corrosion developed at field welds, on bends where wall tubes left an intermediate header extending across the wall, and even in the header itself along the edge toward the furnace. A replacement weld was corroded to the extent shown in Fig. 7 after only three weeks of service. In contrast, very little evidence of attack could be found in a comparable weld removed after a month of service after the control had been changed to maintain from 30 to 50 ppm of free sodium hydroxide in the boiler water. After acid cleaning, the boilers have operated under this

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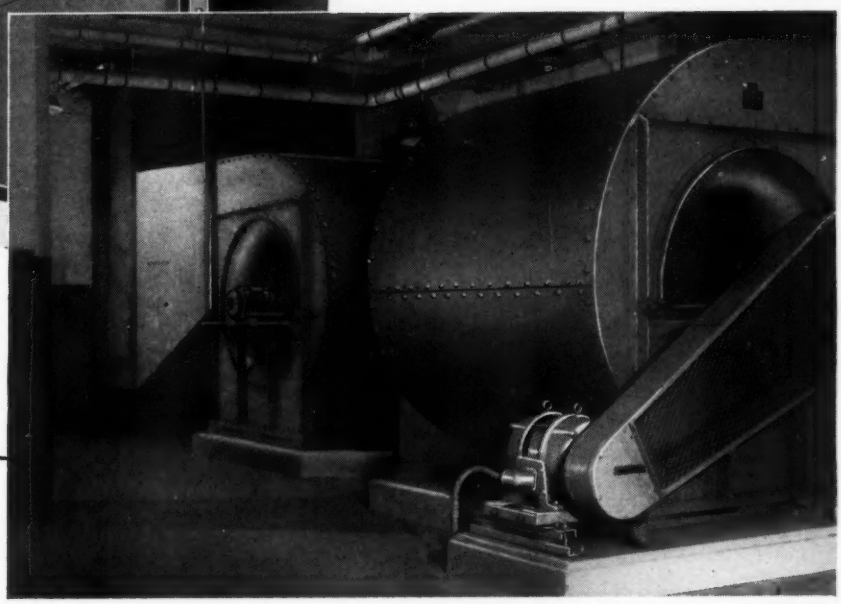

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Acid Cleaning

Whenever iron oxide has accumulated on tube surfaces to the extent that it interferes with heat transfer, with fluid flow, or with the rinsing action necessary to control damage by the concentrating film, a cleaning operation becomes essential. To accomplish this, chemical cleaning with inhibited hydrochloric acid has become standard practice in many central stations. However, this procedure leaves the steel surfaces highly vulnerable to corrosion. Thus, particular attention must be paid to minimizing rust formation while the boiler is idle, and to developing and maintaining an adequate protective film when the unit is in service. From the economic viewpoint, acid cleaning at intervals is scarcely a complete substitute for continuous chemical control of the boiler water. Instead, it is a useful supplementary operation, to be used when necessary to avoid difficulty or to escape from it.

The Optimum Boiler Water

To the mechanical engineer it may seem both arbitrary and inconsistent when the chemical engineer recommends to one plant that free sodium hydroxide be eliminated from the boiler water and to another one that an appreciable concentration of sodium hydroxide be maintained. Yet the evidence is convincing that a boiler with "hot spots" may not be able to endure even a low concentration of caustic. On the other hand, a boiler which does not concentrate the water at any point to an excessive degree actually needs a moderate concentration of hydroxyl ion for its best protection. At any specific installation, judgment is involved which cannot be replaced by a standard recommendation.

The same argument applies to other chemicals used by the chemical engineer for the conditioning of boiler water. Where transfer of silica in the vapor phase from a high pressure boiler to the turbine is a matter of prime importance, precision control of phosphate in the range of only 2 to 5 ppm[22] may be desirable rather than the higher concentration normally carried. Silica removal from the boiler water as magnesium silicate sludge then effectively lessens the tendency of the silica to enter the steam. The development of the optimum boiler water remains a continuing problem in chemical engineering design. Details must be worked out for individual requirements to obtain best economy.

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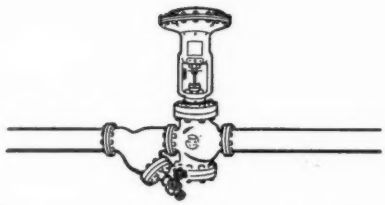

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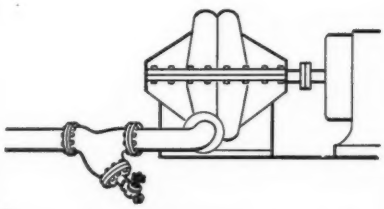

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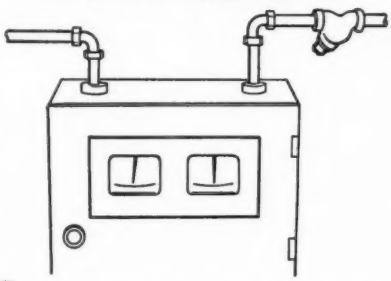

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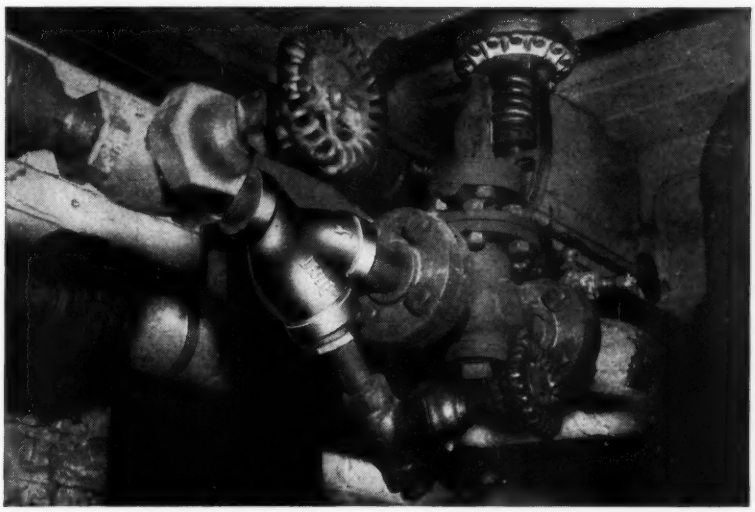

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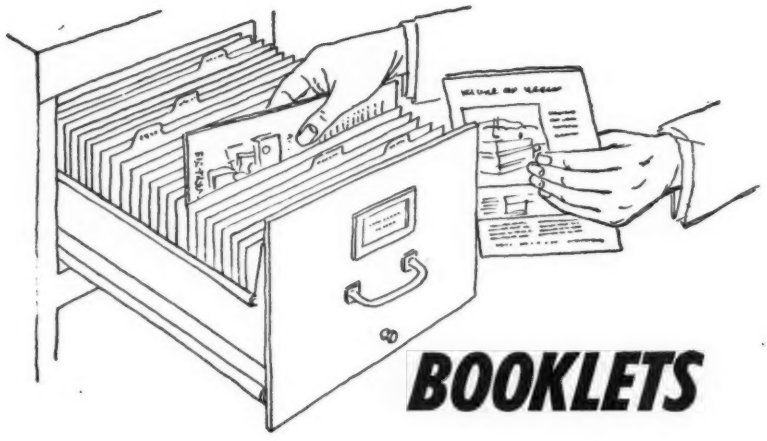

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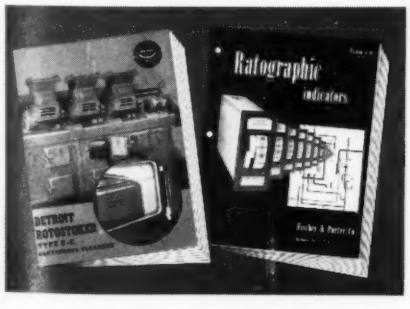

REMOTE MINIATURE INDICATORS, their construction, installation, and design features are described in 12-page bulletin 55-10. Photographs show construction of bellows spring assembly and details of other components. The incorporation of various types of warning devices in the instrument is also explained. Space requirements for panel mounting are given as well as specifications for range of operating air pressures, scale types, graphic color guides or alarms, accuracy, and alarm switches. *Fischer & Porter Co., 11A Jacksonville Rd., Hatboro, Pa.*

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BOILER FEED CONTROL bulletin 1013 illustrates and describes Type 3-L boiler feed control. This is a 3-influence, instrument-type control for heavy duty boilers. The controls described make use of the Copes control valve and combine it with Taylor instruments. *Copes-Vulcan Div., Continental Foundry & Machine Co., Erie 4, Pa.*

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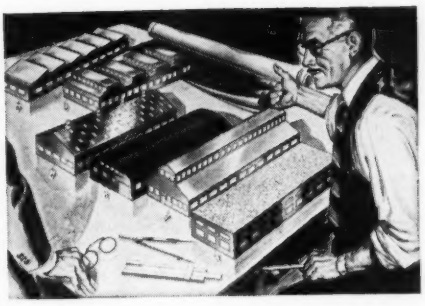

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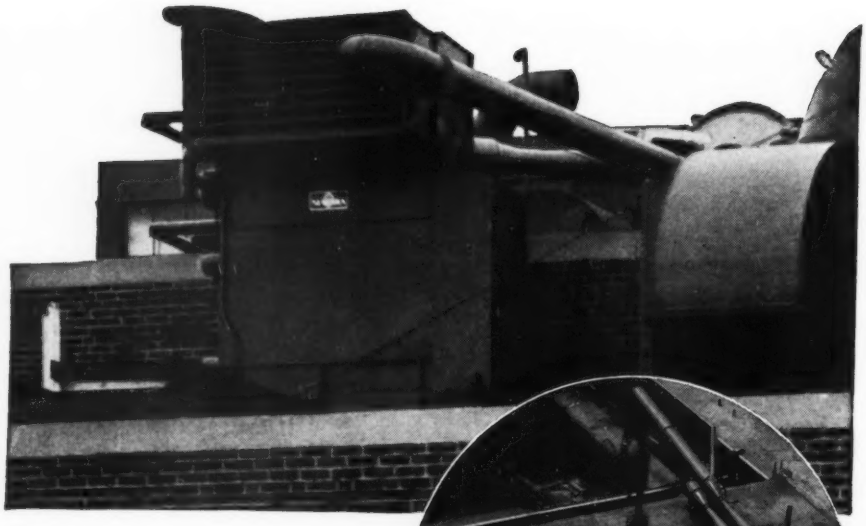

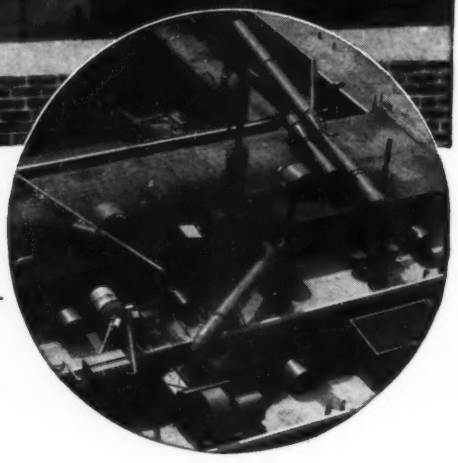

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BOOKLETS

—*Starts on page 74*

"PRODUCTION ENGINEERING," a 4-page folder, gives a practical definition of how products are adapted to production engineering techniques which includes design analysis, production processing, process specification, and work simplification. It includes a description of how these services are applied in the development and testing of prototype production models and special-purpose machinery. *Designers for Industry, Inc., 2915 Detroit Ave., Cleveland 13, Ohio.*

"SERVICES," 22-pages, is a *Who, What, Where,* and *Why* on the applied research, development, and testing offered by this company. The spiral-bound booklet, illustrated with work in progress and shots of test equipment, starts on the tenth floor of the N. Y. laboratories and descends to the first, floor by floor—a guided tour. *Public Relations Dept., Foster D. Snell, Inc., 29 W. 15th St., N. Y. 11, N. Y.*

DATA CARD—to help individuals involved in the design and operation of tubular equipment at elevated temperatures and pressures, data card TDC154 tabulates the maximum allowable stress values (S values) of a complete range of seamless and welded carbon, alloy, and stainless steel tubing and pipe. An adaptation of Table P-7 of the new ASME Boiler Code, it is complete with notes and formulas for the calculation of the maximum allowable working pressures of tubing and pipe. *Sales Office, Tubular Products Div., The Babcock & Wilcox Co., Beaver Falls, Pa.*

TUBULAR CONVEYORS bulletin HEM 124, shows engineering and mechanical details, and illustrates the patented sealed-pin chain design which is said to increase chain life and reduce costs by keeping abrasive materials from reaching chain pins when the conveyor is in motion. It also describes various types of conveyor drive mechanisms, roller turns, and a vibrator which is used to discharge conveyed materials. These conveyors will handle such materials as metal chips, sludges, carborundum dust, wet or dry chemicals, grains, pulverized coal, and ashes and filter cake. *Hapman Conveyors, Inc., Kalamazoo, Mich.*

ELECTRONIC FLOW METERS for measurement of differential pressure, fluid flow, or liquid level are described in a 4-page folder 52-1074-222. Transmission system, pen drive motor, and continuous integrator are explained. *The Hays Corp., Michigan City, Ind.*

PROTECTION FROM SEEPAGE into mortar joints is the subject of 4-page bulletin 8/Du. Diagrams show an aluminum alloy cover which allows for expansion and contraction of the masonry while affording protection against moisture and frost. Photographs give the method of installation and suggested uses. *Dusing & Hunt, Inc., 1927 Elmwood, Buffalo 7, N. Y.*

VERTICAL TURBINE PUMPS and their use in municipal water plants are illustrated in 7-page bulletin W-450-B40. Numerous photographs show typical installations as well as service facilities of the company. *Worthington Corp., Harrison, N. J.*

FLEXIBLE CONDUIT, presented in 4-page folder UA-530, is described as the first flexible liquid-tight electrical wiring conduit of its type to gain UL approval for use in wet locations. Suggested applications and specifications are included. A cutaway view shows construction. *The American Brass Co., American Metal Hose Branch, 692 Main St., Waterbury, Conn.*

MOTOR DRIVES — Purpose of 26-page booklet B5619 is to examine the various conditions under which motor drives must operate in the coal industry, analyze them, and list the particular drives and controls best suited for each condition. Complete descriptions, specifications, and application data are available in free bulletins listed at the back of this booklet. *Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30.*

CONDENSER AND EXCHANGE TUBES handbook is designed to help engineers decide which alloy will give the best service under any particular operative conditions. It presents alloy properties, discusses corrosion, and gives considerable engineering data on metals and tubes. A valuable handbook for engineers. *Bridgeport Brass Co., Bridgeport 2, Conn.*

PIPING & PRESSURE VESSELS—A new company publication is designed to give brief descriptions of recent technical publications and new standards that will be of interest to engineers working with piping and pressure vessels. Issues will also contain digest of recent boiler code and pressure pipe code and other data of interest in this field. *Taylor Forge & Pipe Works, Chicago 90, Ill.*

STRUCTURAL DESIGN WITH ALUMINUM in mind is outlined in *"Technical Advisor,"* No. 21 and 22. This external house organ will help you keep up-to-date on the latest methods for fabricating and processing aluminum and its alloys. *Reynolds Metal Co., Desk PR, 2500 S. 3rd St., Louisville 1, Ky.*

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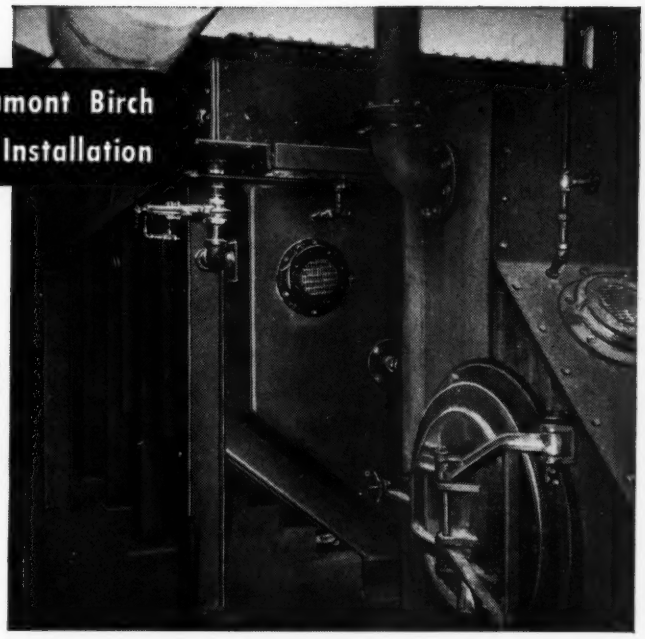

Discharge end section of a flooded hopper for Beaumont hydraulic system showing rugged supporting structure and circular protected observation ports of special heat resistant glass.

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Understanding Explosions, by O. Robert Shurig, CONSULTING ENGINEER, August, 1953; pgs. 39-44

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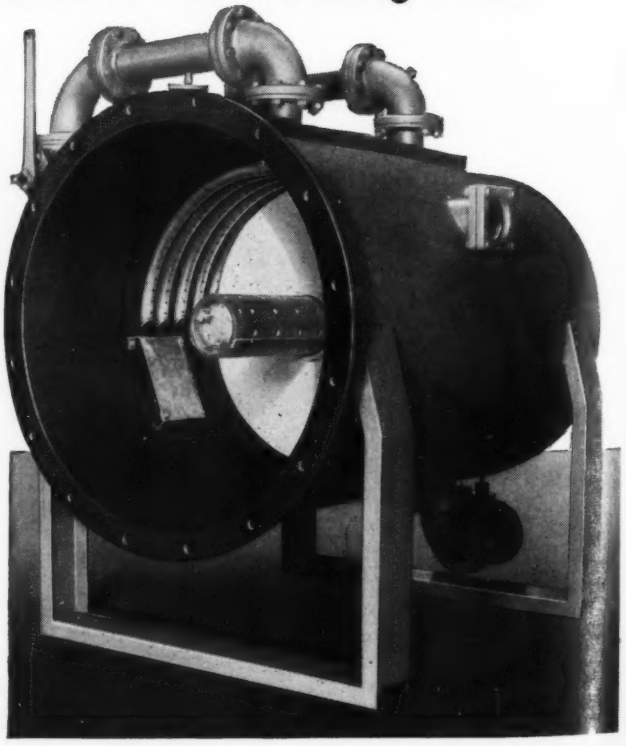

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Oct. 19	American Institute of Consulting Engineers	Annual Dinner	Statler Hotel New York, N. Y.
Oct. 19-22	Society of Industrial Packaging and Materials Handling Engineers	Exposition	Mechanics Hall Boston, Mass.
Oct. 19-23	American Society of Civil Engineers	Annual Meeting	Statler Hotel New York, N. Y.
Oct. 19-23	National Safety Council	National Safety Congress	Conrad Hilton Hotel Chicago, Ill.
Oct. 23-24	Armour Research Foundation	Nation Noise Abatement Symposium	Ill. Inst. of Tech. Chicago, Ill.
Oct. 27	Consulting Chemist and Chem. Eng'rs.	25th Anniversary Meeting	Belmont Plaza Hotel New York, N. Y.
Oct. 28-30	American Management Association	Manufacturing Conference	Belevue-Stratford Philadelphia, Pa.
Oct. 29-30	American Institute of Mining and Metallurgical Engineers — American Society of Mechanical Engineers	Joint Fuels Conference	Conrad Hilton Hotel Chicago, Ill.
Nov. 2-6	American Institute of Electrical Engineers	Fall General Meeting	Hotel Muehlebach Kansas City, Mo.
Nov. 4	American Institute of Consulting Engineers	Luncheon Meeting	City Midday Club New York, N. Y.
Nov. 4-6	Industrial Management Society	Time and Motion Study and Management Clinic	Sheraton Hotel Chicago, Ill.
Nov. 9-12	Refrig. Equip. Mfrs. Assoc.	Refrig. & Air Cond. Exp.	Public Auditorium Cleveland, Ohio
Nov. 29-Dec. 4	American Society of Mechanical Engineers	Annual Meeting	Statler Hotel New York, N. Y.
Nov. 30-Dec. 5	Exposition of Chemical Industries	Exhibit	Commercial Museum Philadelphia, Pa.
Dec. 12-15	American Institute of Chemical Engineers	Annual Meeting	Statler Hotel New York, N. Y.
Dec. 13-16	American Institute of Chemical Engineers	Annual Meeting	Jefferson Hotel St. Louis, Mo.
Jan. 18-22	American Institute of Electrical Engineers	Winter Meeting	Statler Hotel New York, N. Y.
Jan. 25-28	Plant Maintenance & Engineering Show	Exposition	Conrad Hilton Hotel Chicago, Ill.

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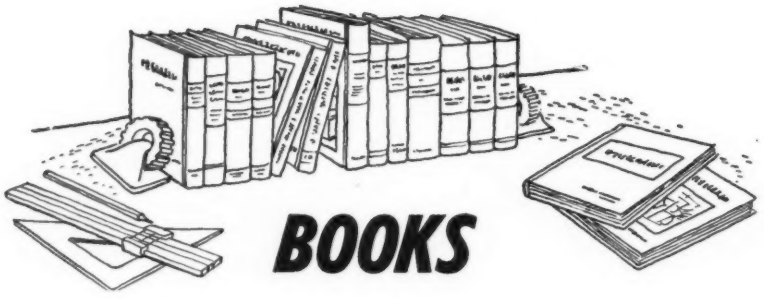

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GAS TURBINES, ANALYSIS AND PRACTICE, by Burgess H. Jennings, Professor and Chairman and Willard L. Rogers, Asst. Professor, Department Mechanical Engineering, The Technical Institute, Northwestern University, McGraw-Hill Book Co., 487 pages, $8.50.

*Reviewed by R. Tom Sawyer**
Manager Research Department
American Locomotive Company

This is a fine book for the student and an excellent reference book for the consulting engineer interested in power plants. As many prior books completely cover gas turbine history, this one only lightly touches it; going into thermodynamics in the second chapter. Many tables and diagrams are included making the book one of the most complete on the subject. In fact one soon realizes that between the covers there is the equivalent of several books, the subjects of which are so basic that they should be useful for many years. The 12 chapters could be regrouped in the following "books":

1. Brief history and description of typical gas turbine power plants of all types. (Chapters 1, 7, and 8) (Not basic data and soon out of date)
2. Gas turbine cycles, air properties and thermodynamics. (Chapters 2 and 3) (Basic data)
3. A-Design of Axial flow turbines and compressors, also radial compressors. (Radial turbines are not included due to so few actually used to date) (Chapters 4, 5, and 6) (Basic data) B-Design of combustors together with fuel tables and combustion characteristics. (Chapter 9) (Basic data)
4. Materials, vibrations, and stresses in turbine plant elements. (Chapters 10, 11, and 12) (Basic data)

Throughout each chapter typical examples are given and at the end of each chapter are problems, each with its answer. This is not only good for the student but all work is plainly written to assist an individual to work out the problems for himself.

There are an average of 15 references at the end of each chapter which greatly broaden the scope of the book for the man interested in all phases of the gas turbine. Many of these references not only refer to basic data used in the book but also refer to articles and papers covering the advancement of the art of gas turbines. The reader should realize that once a book goes to press its contents are "frozen" and he is therefore expected to read the periodicals, technical papers, etc. to keep abreast of the great progress being made by the gas turbine.

In conclusion—this book is a valuable addition to any gas turbine power plant library.

*Mr. Sawyer is author of *The Modern Gas Turbine*, and was the organizer of the present Gas Turbine Power Division of the American Society of Mechanical Engineers.

DIESEL ENGINEERING HANDBOOK, 8th Edition, Diesel Publications, Inc., 827 pages, $7.50.

Reviewed by Ralph H. Miller
Chief Engineer
Four-Cycle Engine Department
Nordberg Manufacturing Company

The Revised Eighth Edition of the Diesel Engineering Handbook should be in the possession of and be required reading for all diesel engine consultants, operators, and maintenance supervisors.

Subjects common to all diesel engines, regardless of make, are treated in a comprehensive manner and grouped in 28 chapters.

As a diesel engine designer, I find

Chapter 11 of particular interest because in that is pointed out the period when the sound theoretical ideas of the scientist Beau de Rochas were corrupted by the practical ideas of Otto and Langen, who evidently developed the false theory which states that the thermal efficiency is a function of the compression ratio. If the correct theory had been taught, namely, that thermal efficiency is a function of expansion ratio only and not the compression ratio, our automobiles today would operate with double the present mileage and high octane fuels would be unnecessary.

This error in the equation expressing thermal efficiency made 70 years ago is still carried in our text books, taught in our best engineering schools, and generally accepted by engineers in the internal combustion industry.

This edition of Diesel Engineering Handbook is the first to include a description of the Miller Internal Combustion Engine System.

PUMPS, 2nd Edition, by Frank A. Kristal and F. A. Annett, McGraw-Hill Book Co., 373 pages, $6.50.

Reviewed by Igor J. Karassik
Manager Multistage Pump Section,
Centrifugal Pump Division,
Worthington Corporation

This is the second edition of a volume presented by the authors in 1940. Avoiding purely theoretical discussion or the presentation of any design factors and design methods, the authors have approached their subject with a view of making the general principles of pumping and the understanding of various construction details and pump types acceptable to the reader regardless of the extent of his formal education.

The book presents first a group of chapters on the construction of various reciprocating, centrifugal, propeller, deep-well, and rotary pumps. It follows with a more detailed discussion on certain special services and applications, such as boiler feed, sewage, sanitary, and proportioning service. A chapter is devoted to the methods of priming pumps, a problem which is to this day little understood by many operators.

It continues with a discussion of *head* and *capacity* requirements, covering the allied problems of lift, effect of specific gravity, viscosity, etc. An interesting chapter describes methods to be used in evaluating the most economical pipe size for a given installation. The book closes with chapters on pump operation, installation, maintenance, and correction of troubles.

The Appendix carries such useful tables as friction losses through rubber hose, equivalents of liquid measures, pressures and other conversion factors, data on irrigation requirements, and swimming pool applications. Such data will be useful to personnel engaged in small pump installations.

The authors have made liberal use of illustrative material supplied by the major portion of the pumping industry. One might complain that equal prominence may have been given to certain very special types rarely encountered in practice or that some of the illustrations are actually obsolete. The criticism, however, is not a very weighty one.

It is also somewhat unfortunate that the authors have retained in this edition certain term definitions from their first edition, terms which in the meantime have become superseded by a more exact terminology. A case in point is the term *total dynamic head* which has been abandoned by the body of pump manufacturers for the simpler term *total head.*

This book should be of particular interest to the non-specialist who finds himself confronted with the application of pumping machinery at rare intervals, and hence seldom has the opportunity of becoming intimate with the problems involved.

ALSO AVAILABLE

PROCEEDINGS, MINNESOTA INTERNATIONAL HYDRAULICS CONVENTION, Hydraulics Division of the American Society Civil Engineers, 576 pages, $6.00. Especially useful for reference purposes, this collection of technical papers includes the work of 75 specialists who have collaborated to present 49 papers on 4 main topics in the field: Basic Relationship of Sediment Transportation by Flowing Water; Density Currents; Air Entrainment by Flowing Water; Waves, Beach Erosion, and Hydromechanics of Shore Structures.

INDUSTRIAL FILMS

"THE EL PASO STORY," color slide film with sound, 12 minutes, General Electric Company, Schenectady 5, N. Y., covers the uses, advantages, and manufacture of the gas turbine for gas pipeline pumping. The film centers around the Cornudas, Texas compressor station of the El Paso Natural Gas Company's Southern Mainline where the first of twenty-eight 5700-hp gas turbines is in operation for the gas transmission system between West Texas and California.

"MECHANICAL SEALS," 20-minute, full-color, Byron Jackson Co., Los Angeles 54, California. Designed for showings to engineering and maintenance meetings, this film covers mechanical seals from design to maintenance, various seal types and their applications. Animated drawings illustrate seal operation. A condensed transcript is available in bulletin form.

Just Published!

GAS TURBINES

ANALYSIS AND PRACTICE

By **B. H. Jennings,** Prof. and Chrmn., Dept. of Mech. Eng., and **W. L. Rogers,** Ass't. Prof. of Mech. Eng. Both of the Technological Inst., Northwestern Univ.

487 pp., 200 illus. $8.50

This thoroughgoing analysis of the modern gas turbine gives you design information . . . operating characteristics . . . and industrial scope and uses of this new source of power. It explains the basic principles of various types of gas turbines and provides a careful coverage of the thermodynamics necessary to an understanding of the subject. You get detailed material on fuels, types of compressors, stresses and strains, the metals used, and the metallurgy involved in the design of efficient, economical power units.

Includes a complete set of Air Tables and Gas Combustion Charts

Principal types and applications of the gas turbine are discussed: jet aircraft power plants, locomotives, marine uses, and stationary power units. In discussing the uses of turbine power, reference is always made to the relative economy of the turbine versus more familiar power equipment.

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8—Power Plant and Transportation Turbine Units
9—Fuels, Combustion and Combustion Chambers
10—Stresses in Turbine Plant Elements
11—Vibration and Balancing
12—Materials and Metallurgy

The book provides the ideal balanced treatment of fundamentals, applications, and examples of modern equipment. Practicing engineers will appreciate its many features, especially its stress on fundamental concepts of thermodynamics, and the extensive coverage of compressor types. Included in this latter section is material on the Lysholm compressor, and the relatively new "free piston" designs.

For engineers who wish a thorough, up-to-date look at the field, this book is recommended.

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